20-1025 (Lead); 20-1138 (Consolidated)

UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT

ENVIRONMENTAL HEALTH TRUST; CONSUMERS FOR SAFE CELL PHONES; ELIZABETH BARRIS; THEODORA SCARATO

CHILDREN'S HEALTH DEFENSE; MICHELE HERTZ; PETRA BROKKEN; DR. DAVID O. CARPENTER; DR. PAUL DART; DR. TORIL H. JELTER; DR. ANN LEE; VIRGINIA FARVER, JENNIFER BARAN; PAUL STANLEY, M.Ed.
Petitioners

v.

FEDERAL COMMUNICATIONS COMMISSION;
UNITED STATES OF AMERICA
Respondents

Petition for Review of Order Issued by the
Federal Communications Commission

DEFERRED JOINT APPENDIX

VOLUME 16

Edward B. Myers
Law Office of Edward B. Myers
14613 Dehaven Court
North Potomac, MD 20878
Phone: 717-752-2032
edwardbmyers@yahoo.com

Counsel for Petitioners 20-1025

Robert F. Kennedy, Jr.
Children's Health Defense
1227 North Peachtree Pkwy #202
Peachtree City, GA 30269
Phone: 845-377-0211
rfk.fcc@childrenshealthdefense.org

W. Scott McCollough
McCollough Law Firm, P.C.
2290 Gatlin Creek Rd.
Dripping Springs, TX 78620
Phone: 512-888-1112
wsmc@dotlaw.biz

Counsel for Petitioners 20-1138

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

Tab No.	JA Page Nos.	Date	Filer/Author	Filing/Attachment Description
7 Part 1	589-764	Sep. 16, 2019	Joel M. Moskowitz PhD	Research Compilation; Abstracts of over 2,100 studies published between 1990 - 2017; Prof. Henry Lai. (Tab 7 Part 1)
VOLUME 3 – Tab 7 Part 2				
7 Part 2	765-1164	Sep. 16, 2019	Joel M. Moskowitz PhD	Research Compilation; Abstracts of over 2,100 studies published between 1990 - 2017; Prof. Henry Lai.(Tab 7 Part 2)
VOLUME 4 – Tab 7 Part 3				
7 Part 3	1165-1564	Sep. 16, 2019	Joel M. Moskowitz PhD	Research Compilation; Abstracts of over 2,100 studies published between 1990 - 2017; Prof. Henry Lai.(Tab 7 Part 3)
VOLUME 5 – Tabs 7 Part 4 – 8 Part 1				
7 Part 4	1565-1602	Sep. 16, 2019	Joel M. Moskowitz PhD	Research Compilation; Abstracts of over 2,100 studies published between 1990 - 2017; Prof. Henry Lai.(Tab 7 Part 4)
8 Part 1	1603-1964	Sep. 13, 2019	Joel M. Moskowitz PhD	Research Compilation; Abstracts of Over 600 Studies Published Between August 2016- August 2019, Dr. Joel Moskowitz; 2019 (Tab 8 Part 1)

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

20	3056-3065	Aug. 27, 2013	Cindy Sage and David O. Carpenter	BioInitiative Comments
21	3066-3080	Nov. 18, 2013	Kevin Mottus	BioInitiative; 2012 Conclusions
22	3081-3126	Nov. 18, 2013	Kevin Mottus	BioInitiative; Section 24: Key Scientific Evidence and Public Health Policy Recommendations; 2012
23	3127-3146	Jul. 11, 2016	Cecelia Doucette	BioInitiative; Section 1: Summary for the Public (2014 Supplement)
VOLUME 9 – Tabs 24-27				
24	3147-3218	Sep. 30, 2016	Catherine Kleiber	BioInitiative-Modulation; Section 15: Evidence for Disruption by Modulation Role of Physical and Biological Variables in Bioeffects of Non-Thermal Microwaves for Reproducibility, Cancer Risk and Safety Standards, (2012 Supplement)
25	3219-3319	Sep. 3, 2013	Kevin Mottus	BioInitiative; Section 20, Findings in Autism, Consistent with Electromagnetic Fields (EMF) and Radiofrequency Radiation (RFR); 2012
26	3320-3321	Sep. 16, 2019	Joel Moskowitz PhD.	BioInitiative-Neurological; Percent Comparison, Effect vs No Effect in Neurological Effect Studies; 2019
27	3322-3559	Sep. 16, 2019	Joel Moskowitz PhD.	BioInitiative-Neurological; Research Summaries, RFR Neurological Effects (Section 8), 2007-2017; 2017

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

35	3772-3779	Apr. 14, 2019	Cindy Sage, MA	BioInitiative Working Group; Epidemiological Studies, RF fields epidemiology, Comments by Drs. Lennart Hardell, Fredrik Soderqvist PhD. and Michael Carlberg, MSc. Section 3.5.1.1 Epidemiological Studies (Exhibit B); 2014
36	3780-3874	Apr 11, 2014	Cindy Sage, MA	BioInitiative Working Group; An Update on the Genetic Effects of Nonionizing Electromagnetic Fields by Prof. Henry Lai PhD; (Exhibit E); 2014
37	3875-3896	Apr. 11, 2014	Cindy Sage, MA	BioInitiative Working Group; An Update on Physical and Biological Variables, Cancer and Safety Standards by Prof. Igor Belyaev Dr. Sc., (Exhibit F); 2014
38	3897-3904	Sep. 30, 2016	Maria Powell	BioInitiative Co-Editor; Human Health Effects of EMFs: The Cost of Doing Nothing. IOPScience. (Prof. David Carpenter MD.); 2010
39	3905-3919	Sep. 28, 2016	Kevin Mottus	BioInitiative Author; Statement of Prof. Martin Blank PhD., PhD.; 2016
40	3920-3945	Aug 27, 2013	Sage Hardell Herbert	BioInitiative Authors; Prof. Lennart Hardell MD. PhD., Prof. Martha Herbert MD. PhD. and Cindy Sage Comments
41	3946-3984	Aug. 26, 2013	B. Blake Levitt & Henry Lai	BioInitiatiive Author; Prof. Henry Lai PhD, and Blake Levitt Comments

INDEX TO DEFERRED APPENDIX

VOLUME 11 – Tabs 42-59				
42	3985-4072	Sep. 3, 2013	Paul Dart MD	Dr. Paul Dart MD. (Petitioner) Comments
43	4073-4102	Feb. 4, 2013	Dr. Andrew Goldsworthy	The Biological Effects of Weak Electromagnetic Fields, Problems and Solutions, Prof. Andrew Goldsworthy; 2012
44	4103-4106	Sep. 4, 2013	Richard Meltzer	Dr. Richard Meltzer Comments, Radio Frequency (RF) Exposure: A Cautionary Tale
45	4107-4112	Feb. 6, 2013	Donald R. Maisch	Dr. Donald R. Maisch PhD. Comments
46	4113-4129	Nov. 18, 2013	Catherine Kleiber	Biological Effects from RF Radiation at Low-Intensity Exposure, based on the BioInitiative 2012 Report, and the Implications for Smart Meters and Smart Appliances; Dr. Ron M. Powell, PhD.; 2013
47	4130-4137	Aug. 20, 2013	Lawrence James Gust	Eng. Lawrence James Gust Comments
48	4138-4146	Feb. 25, 2013	Michael Schwaebe	Eng. Michael Schwaebe Comments
49	4147-4178	Mar. 18, 2015	Environmental Working Group	Organizations; Environmental Working Group Reply Comments
50	4179-4195	Nov. 18, 2013	Nina Beety	Nina Beety Comments

INDEX TO DEFERRED APPENDIX

51	4196-4206	Sep. 16, 2019	Joel Moskowitz PhD.	Organizations; EMF Scientist Appeal, International Scientists' Appeal to the United Nations; 2015
52	4207-4217	Apr. 5, 2018	NancyD	Organizations; 5G Appeal, Scientist Appeal to the EU, Scientists Warn of Potential Serious Health Effects of 5G; 2017
53	4218-4240	Jun. 7, 2017	Environmental Health Trust	Organizations; Medical Doctors and Public Health Organizations: Consensus Statements and Doctors' Recommendations on Cell Phones/Wireless; 2017
54	4241-4244	Sep. 27, 2016	Kevin Mottus	Organizations; Council of Europe, Résolution 1815, The Potential Dangers of Electromagnetic Fields and Their Effect on the Environment; 2011
55	4245-4257	Feb. 5, 2013	Gilda Oman	Organizations; Council of Europe, Parliamentary Assembly Report: The potential dangers of electromagnetic fields and their effect on the environment; 2011
56	4258-4293	Jul. 11, 2016	Environmental Health Trust	Organizations - Radiation Sickness; European Academy for Environmental Medicine, EUROPAEM EMF Guideline 2015 for the prevention, diagnosis and treatment of EMF-related health problems and illnesses; 2015

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

63	4535-4540	Sep. 29, 2016	Kevin Mottus	Organizations; California Medical Association, House of Delegates Resolution Wireless Standards (Resolution 107 - 14); 2014
64	4541-4543	Sep. 3, 2013	Grassroots Environmental Education, Inc. o/b/o American Academy of Environmental	Organizations; American Academy of Environmental Medicine, Letter to the Federal Communications Commission; 2013
65	4544-4561	Sep. 29, 2016	Kevin Mottus	Organizations - Radiation Sickness; Austrian Medical Association, Guidelines for the Diagnosis and Treatment of EMF Related Health Problems and Illnesses (EMF Syndrome); 2011
66	4562-4590	Sep. 28, 2016	Kevin Mottus	Organizations; International Association of Fire Fighters, Position on the Health Effects from Radio Frequency/Microwave Radiation in Fire Department Facilities from Base Stations for Antennas and Towers; 2004
67	4591-4599	Sep. 28, 2016	Kevin Mottus	Organizations; Cities of Boston and Philadelphia Reply Comments
68 Part 1	4600-4800	Sep. 3, 2013	Environmental Working Group	Organizations; Appeal to the FCC Signed by 26,000 People and Organized by the Environmental Working Group, 2013 (Tab 68 Part 1)

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

81	5304-5306	Sep. 3, 2013	The EMR Policy Institute	Medical Treatments & Modulation; Treating cancer with amplitude-modulated electromagnetic fields: a potential paradigm shift, again? British Journal of Cancer. (Dr. Carl Blackman); 2012
82	5307-5309	Feb. 8, 2013	Alan Frey	Modulation; Dr. Alan Frey PhD., Comments, Feb. 7, 2013
83	5310-5319	Jul. 11, 2016	Environmental Health Trust	Modulation; Real Versus Simulated Mobile Phone Exposures in Experimental Studies. Biomed Res Int. (Prof. Panagopoulos et al); 2015
84	5320-5368	Sep. 16, 2019	Joel M. Moskowitz, PhD	Neurological; Book Chapter, A Summary of Recent Literature (2007-2017) on Neurological Effects of Radiofrequency Radiation, Prof. Lai; 2018 Referenced 122 Studies.
85	5369-5412	Sep. 28, 2016	Kevin Mottus	Neurological - Report; Evidence of Neurological effects of Electromagnetic Radiation: Implications for degenerative disease and brain tumour from residential, occupational, cell site and cell phone exposures. Prof. Neil Cherry; 225 scientific references. 2002
86	5413-5415	Sep 3, 2013	Kevin Mottus	Neurological; The effects of mobile-phone electromagnetic fields on brain electrical activity: a critical analysis of the literature. Electromagn Biol Med. (Marino et al) (Abstract); 2009

INDEX TO DEFERRED APPENDIX

87	5416-5435	Nov. 18, 2013	Kevin Mottus	Autism and EMF? Plausibility of a pathophysiological link. Pathophysiology, Part I. (Herbert et al); 2013
88	5436-5460	Nov. 18, 2013	Kevin Mottus	Autism and EMF? Plausibility of a pathophysiological link. Pathophysiology, Part II. (Herbert et al); 2013
89	5461-5486	Sep. 3, 2013	Kevin Mottus	Fertility; Research Abstracts, List of References Reporting Fertility and/or Reproduction Effects from Electromagnetic Fields and/or Radiofrequency Radiation (66 references)
90	5487-5499	Sep. 3, 2013	Paul Dart MD	Fertility; Effects of Microwave RF Exposure on Fertility, Dr. Paul Dart MD. (Petitioner); 2013
91	5500-5506	Sep. 3, 2013	Paul Dart MD	Hormonal; RF and Hormones, Alterations in Hormone Physiology; Dr. Paul Dart MD. (Petitioner); 2013
92	5507-5514	Feb. 7, 2013	Toni Stein	Prenatal & Children; Fetal Radiofrequency Radiation Exposure From 800-1900 Mhz-Rated Cellular Telephones Affects Neurodevelopment and Behavior in Mice. Scientific Reports. (Aldad, Taylor et al); 2012
93	5515-5518	Jul. 7, 2016	Environmental Health Trust	Prenatal & Children; Fetal Exposures and Cell Phones. Studies List. Prof. Hugh Taylor MD.; 2015

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

101	6008-6014	Sep. 28, 2016	Kevin Mottus	Prenatal & Children; Cell phone use and behavioral problems in young children. J Epidemiol Community Health. (Divan et al); 2012
VOLUME 16 - Tabs 102-126				
102	6015-6026	Jul. 7, 2016	Environmental Health Trust	Prenatal & Children; "Cell Phones & WiFi – Are Children, Fetuses and Fertility at Risk?"; 2013
103	6027-6060	Jul. 7, 2016	Environmental Health Trust	Prenatal & Children; Safe Schools 2012, Medical and Scientific Experts Call for Safe Technologies in Schools
104	6061-6067	Sep. 3, 2013	Kevin Mottus	Prenatal & Children - Stem Cells; Microwaves from Mobile Phones Inhibit 53BP1 Focus Formation in Human Stem Cells More Strongly Than in Differentiated Cells: Possible Mechanistic Link to Cancer Risk. Environmental Health Perspectives (Markova, Belyaev et al); 2010
105	6068-6069	Sep. 26, 2016	Angela Tsaing	Radiation Sickness - Children; Angela Tsiang Comments
106	6070-6071	Mar. 5, 2013	Abigail DeSesa	Radiation Sickness - Children; Abigail DeSesa Comments
107	6072-6111	Sep. 28, 2016	Kevin Mottus	Cell Towers - Research Abstract Compilation; 78 Studies Showing Health Effects from Cell Tower Radio Frequency Radiation; 2016
108	6112-6122	Sep. 3, 2013	Paul Dart MD	Cell Towers; Consequences of Chronic Microwave RF Exposure, Dr. Paul Dart MD. (Petitioner)

INDEX TO DEFERRED APPENDIX

109	6123-6132	Jul. 11, 2016	Environmental Health Trust	Cell Towers - Cancer; Meta-Analysis, Long-Term Exposure To Microwave Radiation Provokes Cancer Growth: Evidences From Radars And Mobile Communication Systems. (Yakymenko et al); 2011
110	6133-6148	Sep. 3, 2013	Monnie Ramsell	Cell Towers - Neurological; Changes of Clinically Important Neurotransmitters under the Influence of Modulated RF Fields, A Long-term Study under Real-life Conditions; Umwelt-Medizin-Gesellschaft; (Buchner & Eger); 2011
111	6148-6160	Dec. 10, 2018	Environmental Health Trust	Cell Towers - DNA; Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations. Electromagnetic Biology and Medicine. (Zothansiama et al); 2017
112	6161-6169	Dec. 10, 2018	Environmental Health Trust	Cell Towers - Cancer; Environmental radiofrequency radiation at the Järntorget Square in Stockholm Old Town, Sweden in May, 2018 compared with results on brain and heart tumour risks in rats exposed to 1.8 GHz base station environmental emissions, World Academy of Sciences Journal. (Hardell et al); 2018

INDEX TO DEFERRED APPENDIX

113	6170-6258	Sep. 30, 2016	Catherine Kleiber	Cell Towers; Indian Government, Ministry of Environment and Forest, Report on Possible Impacts of Communication Towers on Wildlife Including Birds and Bees. 919 studies reviewed; 2011
114	6259-6260	Sep. 3, 2013	Kevin Mottus	Cell Towers; Epidemiological evidence for a health risk from mobile phone base stations, Int J Occup Environ Health. (Hardell et al); 2010
115	6261-6289	Sep. 16, 2019	Joel Moskowitz, PhD	Cell Towers; Biological Effects From Exposure to Electromagnetic Radiation Emitted By Cell Tower Base Stations and Other Antenna Arrays. Environ. Rev. (Lai & Levitt); 2010
116	6290-6301	Jul. 11, 2016	Environmental Health Trust	Cell Towers; Research Summaries of Cell Tower Radiation Studies
117	6302-6311	Sep. 30, 2016	Catherine Kleiber	Cell Towers-Wildlife; Electromagnetic Pollution From Phone Masts. Effects on Wildlife; Pathophysiology. (Dr. Alfonso Balmori); 2009
118	6312-6324	Jul. 18, 2106	Environmental Health Trust	Cell Towers - Wildlife; Testimony of Dr. Albert M. Manville, II, PhD., C.W.B, Before the City of Eugene City Planning Department in Opposition to AT&T/Crossfire’s Application for a “Stealth” Cellular Communications Tower; May 6, 2015

INDEX TO DEFERRED APPENDIX

119	6325-6341	Sep. 30, 2016	Catherine Kleiber	Cell Towers - Plants; Radiofrequency Radiation Injures Trees Around Mobile Phone Base Stations. Science of the Total Environment. (Waldmann-Selsam et al); 2016
120	6342-6349	Apr. 8, 2014	M.K. Hickcox	Biosystem & Ecosystem; The Dangers of Electromagnetic Smog, Prof. Andrew Goldsworthy, PhD.; 2007
121	6350-6366	Sep. 3, 2013	The EMR Policy Institute	Biosystem and Ecosystem; Impacts of radio-frequency electromagnetic field (RF-EMF) from cell phone towers and wireless devices on biosystem and ecosystem – a review. Biology and Medicine (Sivani et al.); 2012
122	6367-6379	Oct. 1, 2018	Environmental Health Trust	5G; 5G wireless telecommunications expansion: Public health and environmental implications, Environmental Research. (Dr. Cindy Russell MD.); 2018
123	6380-6383	Oct. 18, 2019	Joel M. Moskowitz PhD	5G; We Have No Reason to Believe 5G is Safe, Dr. Joel Moskowitz PhD., Scientific American; 2019
124	6384-6392	Jul. 11, 2017	Environmental Health Trust	5G - Millimeter Waves; Nonthermal Effects of Extremely High-Frequency Microwaves on Chromatin Conformation in Cells in vitro—Dependence on Physical, Physiological, and Genetic Factors. IEEExPlore. (Belyaev et al); 2000

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

133	6588-6603	Jul. 13, 2016	Parents For Safe Technology	Wi-Fi; 2.45-GHz Microwave Irradiation Adversely Affects Reproductive Function in Male Mouse, Mus Musculus by Inducing Oxidative and Nitrosative Stress. Free Radical Research (Shahin et al); 2014
134	6604-6611	Jul. 7, 2016	Environmental Health Trust	Wi-Fi - Fertility; Immunohistopathologic demonstration of deleterious effects on growing rat testes of radiofrequency waves emitted from conventional Wi-Fi devices. Journal of Pediatric Neurology. (Atasoy et al); 2013
135	6612-6620	Apr. 8, 2014	MK Hickox	Smart Meters: Correcting the Gross Misinformation, Letter by 54 Scientists and MDs; 2012
136	6621-6622	Nov. 18, 2013	Catherine Kleiber	Smart Meters - Radiation Sickness; American Academy of Environmental Medicine, Smart Meter Case Series; 2013
137	6623-6692	Sep. 3, 2013	Rachel Cooper	Smart Meters; Assessment of Radiofrequency Microwave Radiation Emissions from Smart Meters; Sage Associates, Environmental Consultants; 2011
138	6693-6699	Jul. 7, 2016	Environmental Health Trust	Smart Meters; FCC Maximum Permissible Exposure Limits for Electromagnetic Radiation, as Applicable to Smart Meters. Dr. Ron Powell PhD.; 2013

INDEX TO DEFERRED APPENDIX

139	6700-6705	Jul. 7, 2016	Environmental Health Trust	Smart Meters - Radiation Sickness; Symptoms after Exposure to Smart Meter Radiation. Dr. Ron Powell PhD.; 2015
140	6706-6735	Sep. 3, 2013	Kit Weaver	Kit Weaver, Comments
141	6736-6740	Feb. 6, 2013	Joshua Hart	Organizations - Radiation Sickness; StopSmartMeters, Comments
142 Part 1	6741-6850	Sep. 28, 2016	Kevin Mottus	Cell Phones; Research Abstracts of Over 700 Studies Showing Health Effects from Cell Phone Radio Frequency Radiation; Prof. Henri Lai (Tab 142 Part 1)
VOLUME 18 – Tabs 142 Part 2 - 153				
142 Part 2	6851-7088	Sep. 28, 2016	Kevin Mottus	Cell Phones; Research Abstracts of Over 700 Studies Showing Health Effects from Cell Phone Radio Frequency Radiation; Prof. Henri Lai (Tab 142 Part 2)
143	7089-7099	Sep. 28, 2016	Kevin Mottus	Cancer - Brain Tumors; Using the Hill viewpoints from 1965 for evaluating strengths of evidence of the risk for brain tumors associated with the use of mobile and cordless phones. Rev Environ Health. (Hardell and Caarlsberg); 2013

INDEX TO DEFERRED APPENDIX

144	7100-7121	Nov. 18, 2013	Kevin Mottus	Cancer-Brain Tumors; Mobile phone use and brain tumour risk: early warnings, early actions? (Gee, Hardell Carlsberg) (Chapter 21 of Report: "Late lessons from early warnings: science, precaution"); 2013
145	7122-7134	Sep. 12, 2019	Environmental Health Trust	Cell Phones; Real-world cell phone radiofrequency electromagnetic field exposures. Environmental Research. (Wall et al); 2019
146	7135-7142	Nov. 18, 2013	Kevin Mottus	Cancer -Brain Tumors; Meta-analysis of long-term mobile phone use and the association with brain tumours, Prof. Lennart Hardell MD. PhD. 2008
147	7143-7156	Jul. 11, 2016	Environmental Health Trust	Cancer - Brain Tumors; Case-control study of the association between malignant brain tumours diagnosed between 2007 and 2009 and mobile and cordless phone use. International Journal of Oncology.(Hardell et al); 2013
148	7157-7183	Nov. 18, 2013	Kevin Mottus	Cancer - Brain Tumors; Use of mobile phones and cordless phones is associated with increased risk for glioma and acoustic neuroma. Pathophysiology. (Hardell et al); 2012

INDEX TO DEFERRED APPENDIX

149	7184-7193	Sep. 28, 2016	Kevin Mottus	Cancer - Brain Tumors; Pooled Analysis of Two Swedish Case-Control Studies on the Use of Mobile and Cordless Telephones and the Risk of Brain Tumours Diagnosed During 1997-2003.International Journal of Occupational Safety and Ergonomics (Mild, Hardell, Carlsberg); 2007
150	7194-7210	Dec. 10, 2018	Environmental Health Trust	Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective. Environmental Pollution. (Belpomme et al); 2018
151	7211-7224	Sep. 28, 2016	Kevin Mottus	Cancer - Brain Tumors; Mobile phones, cordless phones and the risk for brain tumours. International Journal of Oncology (Prof. Lennart Hardell MD., PhD.); 2009
152	7225-7251	Sep. 3, 2013	Paul Dart MD	Cancer - Cell Phones; Cell Phones and Risk of Brain Tumor, Dr. Paul Dart MD. (Petitioner); 2013
153	7252-7255	Jan 31, 2019	Julian Gehman	Jullian Gehman Esq. Comments
VOLUME 19 – Tabs 154-168				
154	7256-7371	Nov. 5, 2013	Joel M. Moskowitz Ph.D.	Dr. Joel Moskowitz PhD. Reply Comments, Why the FCC Must Strengthen Radiofrequency Radiation Limits in the U.S.

INDEX TO DEFERRED APPENDIX

155	7372-7414	Jun. 17, 2014	Environmental Working Group	Cancer - Children; Cell Phone Radiation: Science Review on Cancer Risks and Children's Health; Environmental Working Group; 2009
156	7415-7417	Sep. 30, 2016	Kevin Mottus	Cell Phones - Plants; Review: Weak Radiofrequency Radiation Exposure From Mobile Phone Radiation on Plants. Electromagnetic Biology and Medicine (Malka N. Halgamuge); 2016
157	7418-7421	Apr. 29, 2019	Environmental Health Trust	Testing; Microwave Emissions From Cell Phones Exceed Safety Limits in Europe and the US When Touching the Body. IEEE Access. Prof. Om P. Gandhi PhD.; 2019
158	7422-7426	Sep. 12, 2019	Environmental Health Trust	Testing - Children; Absorption of wireless radiation in the child versus adult brain and eye from cell phone conversation or virtual reality. Environmental Research. (C. Fernandez et al); 2018
159	7427-7431	Jul. 11, 2016	Environmental Health Trust	Yes the Children Are More Exposed to Radiofrequency Energy From Mobile Telephones Than Adults. IEEE Access (Prof. Om Ghandi PhD); 2015
160	7432-7441	Jul. 7, 2016	Environmental Health Trust	Testing - Children; Children Absorb Higher Doses of Radio Frequency Electromagnetic Radiation From Mobile Phones Than Adults. IEEE Access (Robert D. Morris et al); 2015

INDEX TO DEFERRED APPENDIX

161	7442-7445	Apr. 29, 2019	Environmental Health Trust	Testing – Children; Exposure Limits: The underestimation of absorbed cell phone radiation, especially in children. Electromagnetic Biology and Medicine (Gandhi et al); 2011
162	7446-7504	Nov. 17, 2013	Pong Research Corporation	Testing; Pong Research Corporation Reply Comments
163	7505-7514	Aug. 19, 2012	Pong Research Corporation	Testing; Pong Research Corporation, Letter to the FCC
164	7515-7602	Nov. 17, 2013	L. Lloyd Morgan	Environmental Health Trust, Reply Comments (Erroneous Comments Submitted to the FCC on Proposed Cellphone Radiation Standards and Testing by CTIA – September 3, 2013)
165	7603-7614	Sep. 3, 2013	Dr. Joel M. Moskowitz PhD	"Comments on Notice of Inquiry, ET Docked No. 13-84" GAO Report | "Exposure and Testing Requirements for Mobile Phones Should Be Reassessed." Dr. Joel Moskowitz PhD.; 2012
166	7615-7628	Sep. 2, 2013	Consumers for Safe Cell Phones	Organizations; Consumers for Safe Cell Phones Comments (Petitioner)
167	7629-7640	Nov. 17, 2013	Consumers for Safe Cell Phones	Consumers for Safe Cell Phone Comments (Reply to CTIA Comments from Sep. 13, 2013)
168	7641-7672	Nov. 17, 2013	Environmental Working Group	Organizations; Environmental Working Group, Reply Comments

INDEX TO DEFERRED APPENDIX

VOLUME 20 - Tabs 169 – 172 Part 1				
169	7673-7682	Dec. 10, 2018	Environmental Health Trust	Industry Influence; World Health Organization, Radiofrequency Radiation and Health - a Hard Nut to Crack (Review). International Journal of Oncology. Prof. Lennart Hardell MD. PhD.; 2017
170	7683-7716	Nov. 18, 2013	Richard H. Conrad PhD	Industry Influence; Business Bias As Usual: The Case Of Electromagnetic Pollution. Prof. Levis, Prof. Gennaro, Prof. Garbisa
171	7717-7719	Sep. 3, 2013	The EMR Policy Institute	Industry Influence; Prof. Martha Herbert MD PhD., Harvard Pediatric Neurologist Letter to Los Angeles Unified School District; 2013
172 Part 1	7720-8073	Feb. 6, 2013	Dr. Donald R. Maisch PhD	Industry Influence; The Procrustean Approach: Setting Exposure Standards for Telecommunications Frequency Electromagnetic Radiation, Dr. Donald Maisch PhD.; 2009 (Tab 172 Part 1)
VOLUME 21 – Tabs 172 Part 2 - 185				
172 Part 2	8074-8158	Feb. 6, 2013	Dr. Donald R. Maisch PhD	Industry Influence; The Procrustean Approach: Setting Exposure Standards for Telecommunications Frequency Electromagnetic Radiation, Dr. Donald Maisch PhD.; 2009 (Tab 172 Part 2)
173	8159-8167	Sep. 29, 2016	Kevin Mottus	Industry Influence; Illusion and Escape: The Cell Phone Disease Quagmire. Dr. George L. Carlo PhD., JD.; 2008

INDEX TO DEFERRED APPENDIX

174	8168-8169	Nov. 18, 2013	Kevin Mottus	Industry Influence; Quote of Prof. Henry Lai PhD from NY Times Article about Percent of Negative Studies Funded By Industry; 2013
175	8170-8177	Nov 18, 2013	Kevin Mottus	Industry Influence; Warning: Your Cell Phone May Be Hazardous to Your Health. Christopher Ketcham, GQ; 2010
176	8178-8182	Sep. 3, 2013	Monnie Ramsell	Industry Influence; Radiation Protection in Conflict With Science; Dr. Franz Adlkofer PhD.; 2011
177	8183-8184	Mar. 21, 2019	Office of Engineering and Technology	US Agencies; Letter from the FCC's OET Dept. to Dr. Shuren of the FDA
178	8185-8188	Apr. 30, 2019	Center for Devices and Radiological Health	US Agencies; Letter from Dr. Shuren of the FDA to the FCC's OET Dept.
179	8189-8279	Sep. 24, 2013	Grassroots Environmental Education, Inc.	US Agencies - Radiation Sickness; US Access Board Acknowledgement of Radiation Sickness (Electromagnetic Sensitivities); 2002
180	8280-8377	Sep. 24, 2013	Grassroots Environmental Education, Inc.	US Agencies - Radiation Sickness; National Institute of Building Sciences (NIBS), IEQ Indoor Environmental Quality; Recommendations for Accommodation for Electromagnetic Sensitivity; 2005

INDEX TO DEFERRED APPENDIX

181	8378-8386	Sep. 29, 2016	Kevin Mottus	US Agencies; US Department of Interior, Letter of the Director of Office of Environmental Policy and Compliance; 2014
182	8387-8407	Mar. 4, 2013	Susan Brinchman, CEP	US Agencies; Department of the Army, Confidential Legal Correspondence, Dec. 13, 2006
183	8408-8411	Sep. 2, 2013	Kevin Mottus	US Agencies; US Environmental Protection Agency (EPA) Letter to EMR Network; Jul. 6, 2002
184	8412-8424	Jul. 7, 2016	Environmental Health Trust	US Agencies; EPA Letter to the FCC, Comments on FCC 93-142 Environmental Effects of RF; 1993
185 Part 1	8425-8505	Jul. 7, 2016	Environmental Health Trust	US Agencies; US Naval Medical Research Institute. Bibliography of Reported Biological Phenomena ("Effects") and Clinical Manifestations Attributed to Microwave and Radio-frequency Radiation; 1971 (Tab 185 Part 1)
VOLUME 22 – Tabs 185 Part 2 - 238				
185 Part 2	8506-8531	Jul. 7, 2016	Environmental Health Trust	US Agencies; US Naval Medical Research Institute. Bibliography of Reported Biological Phenomena ("Effects") and Clinical Manifestations Attributed to Microwave and Radio-frequency Radiation; 1971 (Tab 185 Part 2)
186	8532-8636	Jul. 12, 2015	U.S. Department of Labor	US Agencies; US Department of Labor Comment

INDEX TO DEFERRED APPENDIX

187	8537-8539	Sep. 29, 2016	Kevin Mottus	Radiation Sickness; Exemption for Fire stations, California Assembly Bill No. 57 (2015), codified at Cal. Gov. Code 65964.1
188	8540-8546	Sep. 3, 2013	Susan D. Foster, MSW	Radiation Sickness - Firefighters; Susan Foster Comments
189	8547-8626	Jul. 7, 2016	Environmental Health Trust	Radiation Sickness; Electromagnetic Hypersensitivity, Dr. Erica Mallery-Blythe; 2014
190	8627-8628	Sep. 16, 2019	Joel M. Moskowitz PhD.	Radiation Sickness; Reliable disease biomarkers characterizing and identifying electrohypersensitivity and multiple chemical sensitivity as two etiopathogenic aspects of a unique pathological disorder. Rev Environ Health. (Prof. Belpomme et al); 2015
191	8629-8637	Sep.3, 2013	Kevin Mottus	Radiation Sickness; Electromagnetic hypersensitivity: evidence for a novel neurological syndrome. Int J Neurosci. (McCarty et al); 2011
192	8638-8641	Nov. 18, 2013	Toril H. Jelter MD	Radiation Sickness - Children; Dr. Torill Jelter MD. (Petitioner) Comments
193	8642-8659	Jul. 13, 2016	Deborah Kopald	Radiation Sickness, Deborah Kopald Comments
194	8660-8662	Sep. 30, 2016	Ann Lee MD	Radiation Sickness - Children; Dr. Ann Lee MD. (Petitioner) Comments

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

204	8788-8789	Nov. 25, 2013	Lynnell Rosser	Radiation Sickness; Lynnell Rosser Letter
205	8790-8796	Sep.12, 2013	Charyl Zehfus	Radiation Sickness; Charyl Zehfus Reply Comments
206	8797-8800	Sep. 4, 2013	Annie Starr	Radiation Sickness; Annie Starr Comments
207	8801-8802	Sep. 3, 2013	Rob Bland	Radiation Sickness; Rob Bland Comments
208	8803-8805	Sep. 3, 2013	Nancy Rose Gerler	Radiation Sickness; Nancy Rose Gerler Comments
209	8806-8811	Feb. 5, 2013	Monnie Ramsell	Radiation Sickness; Monnie Ramsell Comments
210	8812-8815	Sep. 3 2013	Miriam D. Weber	Radiation Sickness; Miriam D. Weber Comments
211	8816-8818	Sep. 3 2013	Junghie Elky	Radiation Sickness; Junghie Elky Comments
212	8819-8832	Aug. 30, 2013	Catherine Kleiber	Radiation Sickness; ADA/FHA Catherine Kleiber Comments
213	8833-8837	Sep. 3, 2013	Amanda & Ryan Rose	Radiation Sickness; Amanda & Ryan Rose Comments
214	8838-8842	Sep. 3, 2013	Cindy Bowman	Radiation Sickness; Cindy Bowman Comments
215	8843-8844	Sep. 3, 2013	Sue Martin	Radiation Sickness; Sue Martin Comments
216	8845-8846	Sep. 3, 2013	Richard Gaul	Radiation Sickness; Richard Gaul Comments

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

230	8904-8907	Sep. 3, 2013	Ellen K. Marks	Radiation Sickness; Ellen K. Marks Comments
231	8908-8911	Sep. 3, 2013	Melo11dy Graves	Radiation Sickness; Melody Graves Comments
232	8912-8913	Sep. 3, 2013	Bernadette Johnston	Radiation Sickness; Bernadette Johnston Comments
233	8914-8916	Sep. 3, 2013	Shane Gregory	Radiation Sickness; Shane Gregory Comments
234	8917-8918	Sep. 3, 2013	Layna Berman	Radiation Sickness; Layna Berman Comments
235	8919-8922	Sep. 3, 2013	Linda Giannoni	Radiation Sickness; Linda Giannoni Comments
236	8923-8925	Sep. 3, 2013	Jennifer Page	Radiation Sickness; Jennifer Page Comments
237	8926-8928	Sep. 3, 2013	Jackie Seward	Radiation Sickness; Jackie Seward Comments
238	8929-8931	Sep. 3, 2013	Elizabeth Feudale	Radiation Sickness; Elizabeth Feudale Comments
VOLUME 23 – Tabs 239-315				
239	8932-8933	Sep. 3, 2013	Brent Dalton	Radiation Sickness; Brent Dalton Comments
240	8934-8937	Sep. 3, 2013	Elizabeth Barris	Radiation Sickness; Elizabeth Barris (Petitioner) Comments
241	8938-8940	Sep. 3, 2013	Olemara	Radiation Sickness; Olemara Comments
242	8941-8943	Aug. 14, 2013	Melissa White	Radiation Sickness; Melissa White Comments

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

256	9026-9029	Feb. 5, 2013	Odessa Rae	Radiation Sickness; Odessa Rae Comments
257	9030-9033	Feb. 5, 2013	Kenneth Linoski	Radiation Sickness; Kenneth Linoski Comments
258	9034-9039	Feb. 6, 2013	Elissa Michaud	Radiation Sickness; Elissa Michaud Comments
259	9040-9043	Feb. 5, 2013	Ella Elman	Radiation Sickness; Ella Elman Comments
260	9044-9047	Feb. 5, 2013	Andrew Swerling	Radiation Sickness; Andrew Swerling Comments
261	9048-9051	Feb. 5, 2013	Natalie Smith	Radiation Sickness; Natalie Smith Comments
262	9052-9055	Feb. 4, 2013	Mana Iluna	Radiation Sickness; Mana Iluna Comments
263	9056-9059	Feb. 4, 2013	Jayne G. Cagle	Radiation Sickness; Jayne G. Cagle Comments
264	9060-9063	Feb. 4, 2013	Mark Summerlin	Radiation Sickness; Mark Summerlin Comments
265	9064-9067	Feb. 4, 2013	Lashanda Summerlin	Radiation Sickness; Lashanda Summerlin Comments
266	9068-9071	Feb. 4, 2013	Kath Mason	Radiation Sickness; Kath Mason Comments
267	9072-9084	Nov. 1, 2013	Daniel Kleiber	Radiation Sickness; Daniel Kleiber Reply Comments
268	9085-9086	Sep.3, 2013	Susan MacKay	Radiation Sickness; Susan MacKay Comments

INDEX TO DEFERRED APPENDIX

269	9087-9091	Mar. 4, 2013	Theresa McCarthy	Radiation Sickness; Theresa McCarthy Reply Comments
270	9092-9093	Jul. 11, 2016	L S Murphy	Radiation Sickness; L S Murphy Comments
271	9094-9096	Aug. 30, 2013	Patricia B. Fisken	Radiation Sickness; Patricia B. Fisken Comments
272	9097-9098	Sep. 3, 2013	Linda Hart	Radiation Sickness; Linda Hart Comments
273	9099-9101	Aug. 19, 2013	E Renaud	Radiation Sickness; E Renaud Comments
274	9102-9108	Aug. 13, 2013	Nicole Nevin	Radiation Sickness; Nicole Nevin Comments
275	9109-9110	Sep. 30, 2016	Robert VanEchaute	Radiation Sickness; Robert VanEchaute Comments
276	9111-9112	Sep. 6, 2016	Daniel Berman	Radiation Sickness; Daniel Berman Comments
277	9113-9116	Sep. 3, 2013	Edna Willadsen	Radiation Sickness; Edna Willadsen Comments
278	9117-9118	Aug. 30, 2013	Susan Molloy	Radiation Sickness; Susan Molloy Comments
279	9119-9120	Sep. 3, 2013	Kathleen Christofferson	Radiation Sickness; Kathleen Christofferson Comments
280	9121-9122	Sep. 3, 2013	Juli Johnson	Radiation Sickness; Juli Johnson Comments
281	9123-9124	Sep. 3, 2013	Annalee Lake	Radiation Sickness; Annalee Lake Comments

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

296	9181-9182	Sep. 3, 2013	Victoria Jewett	Radiation Sickness; Victoria Jewett Comments
297	9183-9185	Sep. 3, 2013	Michael J. Hazard	Radiation Sickness; Michael J. Hazard Comments
298	9186-9187	Aug. 30, 2013	Melinda Wilson	Radiation Sickness; Melinda Wilson Comments
299	9188-9191	Aug. 30, 2013	Maggi Garloff	Radiation Sickness; Maggi Garloff Comments
300	9192-9199	Sep. 3, 2013	Holly Manion	Radiation Sickness & ADA/FHA; Holly Manion Comments
301	9200-9203	Aug. 22, 2013	James Baker	Radiation Sickness; James Baker Comments
302	9204-9254	Jul. 19, 2013	Deborah Cooney	Radiation Sickness; Deborah Cooney, Verified Complaint, *Cooney v. California Public Utilities Commission et al*, No. 12-cv-06466-CW, U.S.D.C. N.D. Cal. (Dec 17, 2012)
303	9255-9258	Jun. 13, 2013	Mardel DeBuhr	Radiation Sickness; Mardel DeBuhr Comments
304	9259-9260	Jun. 10, 2013	Richard Wolfson	Radiation Sickness; Richard Wolfson Comments
305	9261-9264	Mar. 7, 2013	James E. Peden	Radiation Sickness; James E. Peden Reply Comments
306	9265-9266	Mar. 5, 2013	Carl Hilliard	Radiation Sickness; Carl Hilliard Comments
307	9267-9268	Mar. 4, 2013	Lisa Horn	Radiation Sickness; Lisa Horn Comments

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

333	9388-9391	Mar. 7, 2013	Marilyn L. Peden	Radiation Sickness; Marilyn L. Peden Reply Comments
334	9392-9393	Mar. 5, 2013	Doreen Almeida	Radiation Sickness; Doreen Almeida Reply Comments
335	9394-9395	Mar. 5, 2013	Oriannah Paul	Radiation Sickness; Oriannah Paul Comments
336	9396-9397	Sep. 3, 2013	Heather Lane	Radiation Sickness; Heather Lane Comments
337	9398-9399	Aug. 15, 2013	John Grieco	Radiation Sickness; John Grieco Comments
338	9400-9401	Sep. 29, 2016	Linda Kurtz	Radiation Sickness & ADA/FHA; Linda Kurtz Comments
339	9402-9406	Feb. 5, 2013	Lisa Drodt-Hemmele	Radiation Sickness & ADA/FHA; Lisa Drodt-Hemmele Comments
340	9407-9409	Aug. 26, 2013	Robert S Weinhold	Radiation Sickness & ADA/FHA; Robert S Weinhold Comments
341	9410-9411	Jul. 12, 2016	Dianne Black	Radiation Sickness & ADA/FHA; Dianne Black Comments
342	9412-9415	Jul. 13, 2016	Derek C. Bishop	Radiation Sickness & ADA/FHA; Derek C. Bishop Comments
343	9416-9435	Aug. 21, 2013	Steven Magee	Radiation Sickness & ADA/FHA; Steven Magee Comments
344	9436-9437	Sep. 3, 2013	Melissa Chalmers	Radiation Sickness & ADA/FHA; Melissa Chalmers Comments

INDEX TO DEFERRED APPENDIX

345	9438-9440	Aug. 30, 2013	Garril Page	Radiation Sickness & ADA/FHA; Garril Page Comments
346	9441-9444	Sep. 5, 2013	Laddie W. Lawings	Radiation Sickness & ADA/FHA; Laddie W. Lawings Comments
347	9445-9446	Sep. 4, 2018	Fern Damour	Radiation Sickness & ADA/FHA; Fern Damour Comments
348	9447-9449	Aug. 28, 2013	Rebecca Rundquist	Radiation Sickness & ADA/FHA; Rebecca Rundquist Comments
349	9450-9451	Sep. 3, 2013	JoAnn Gladson	Radiation Sickness & ADA/FHA; JoAnn Gladson Comments
350	9452-9453	Jul. 13, 2016	Jonathan Mirin	Radiation Sickness & ADA/FHA; Jonathan Mirin Comments
351	9454-9455	Jul. 12, 2016	Mary Adkins	Radiation Sickness & ADA/FHA; Mary Adkins Comments
352	9456-9458	Sep. 3, 2013	Ian Greenberg	Radiation Sickness & ADA/FHA; Ian Greenberg Comments
353	9459-9462	Sep. 3, 2013	Helen Sears	Radiation Sickness & ADA/FHA; Helen Sears Comments
354	9463-9464	Mar. 4, 2013	Janet Johnson	Radiation Sickness & ADA/FHA; Janet Johnson Comments
355	9465-9467	Aug. 20, 2013	Mr. and Mrs. Gammone	Radiation Sickness & ADA/FHA; Mr. and Mrs. Gammone Comments
356	9468-9475	Sep. 10, 2013	Shelley Masters	Radiation Sickness - Disability; Shelley Masters Comments

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

INDEX TO DEFERRED APPENDIX

391	10078-10086	Mar. 3, 2013	Sandra Schmidt	ADA/FHA; Sandra Schmidt Reply Comments
392	10087-10099	Feb. 11, 2013	Antoinette Stein	ADA/FHA; Antoinette Stein Comments
393	10100-10103	Feb. 5, 2013	David Morrison	ADA/FHA; David Morrison Comments
394	10104-10107	Apr. 16, 2014	MK Hickox	MK Hickox Reply Comments
395	10108-10009	Sep. 3, 2013	Annemarie Weibel	ADA/FHA; Annemarie Weibel Comments
396	10110 - 10117	Sep. 3, 2013	Omer Abid, MD, MPH	Individual Rights; Dr. Omer Abid MD. MPH Comments
397	10118-10120	Sep. 2, 2013	John A. Holeton	Individual Rights; John & Pauline Holeton Comments
398	10121-10129	Sep. 2, 2013	Grassroots Environmental Education, Inc. o/b/o Nancy Naylor	Individual Rights; Nancy Naylor Comments
399	10130-10143	Sep. 2, 2013	Deborah M. Rubin	Individual Rights; Deborah M. Rubin Comments
400	10,144-10149	Sep. 2, 2013	Kevin Mottus	Individual Rights; Kevin Mottus Comments
401	10150 - 10157	Aug. 30, 2013	Alexandra Ansell	Individual Rights; Alexandra Ansell Comments
402	10158-10161	Aug. 25, 2013	Steen Hviid	Individual Rights; Steen Hviid Comments
403	10162-10165	Aug. 21, 2013	Molly Hauck	Individual Rights; Molly Hauck Comments

INDEX TO DEFERRED APPENDIX

404	10166-10171	Feb. 5, 2013	Olle Johansson	Individual Rights; Prof. Olle Johansson PhD., Comments
VOLUME 26 – Tabs 405-443				
405	10172-10174	Mar. 4, 2013	R.Paul and Kathleen Sundmark	Individual Rights; R. Paul and Kathleen Sundmark Reply Comments
406	10175-10180	Feb. 5, 2013	Cynthia Edwards	Individual Rights & ADA; Cynthia Edwards Comments
407	10181-10185	Feb. 4, 2013	Diana Ostermann	Individual Rights; Diana Ostermann Comments
408	10186-10193	Jul. 13, 2016	Chris Nubbe	Individual Rights; Chris Nubbe Comments
409	10194-10201	Nov. 17, 2013	Katie Singer	Individual Rights & ADA; Katie Singer Comments
410	10202-10203	Aug. 21, 2013	John Puccetti	Individual Rights; BC Human Rights Tribunal approves smart meter class action, Citizens for Safe Technology
411	10204-10207	Sep. 30, 2016	Catherine Kleiber	Individual Rights; Wireless Technology Violates Human Rights, Catherine Kleiber
412	10208-10212	Oct. 28, 2013	Kate Reese Hurd	Individual Rights; Kate Reese Hurd Comments
413	10213-10214	Sep. 30, 2016	Patricia Burke	Individual Rights; Wireless ““Revolution” Must Be Supported by Scientific Proof of Safety for Human Health and the Environment, Patricia Burke

INDEX TO DEFERRED APPENDIX

414	10215-10216	Sep. 3, 2013	Ed Friedman	Individual Rights; Transcript of Hearing, Vol. 10, Application 11-03-014, Application of Pacific Gas and Electric Company for Approval of Modifications to its SmartMeter™ Program and Increased Revenue Requirements to Recover the Costs of the Modifications, California Public Utilities Commission; Dec. 20, 2012
415	10235-10248	Dec. 1, 2013	Julienne Battalia	Individual Rights; Letter of Complaint and Appeal, and Notice of Liability Regarding 'Smart Meter' and Wireless Networks, Julienne Battalia, Washington State
416	10249-10270	Jul. 7, 2016	Environmental Health Trust	Precautionary Principle; Mobile Phone Infrastructure Regulation in Europe: Scientific Challenges and Human Rights Protection, Professor Susan Perry, (international human rights law) Professor Claudia Roda (Impacts of digital technology on human behavior and social structure)
417	10271-10275	Jul. 11, 2016	Environmental Health Trust	Precautionary Principle; Wi-Fi - Children; Saying Good-Bye to WiFi A Waldorf School Takes a Precautionary Step, Dr. Ronald E. Koetzsch PhD.

INDEX TO DEFERRED APPENDIX

418	10276-10290	Jul. 7, 2016	Environmental Health Trust	Precautionary Principle; Wireless Devices, Standards, and Microwave Radiation in the Education Environment, Dr. Gary Brown, Ed.D. (Instructional Technologies and Distance Education)
419	10291-10294	Nov. 18, 2013	Richard H. Conrad, Ph.D.	Precautionary Principle; Dr. Richard H. Conrad Reply Comments
420	10295-10304	Sep. 3, 2013	Holly Manion	Precautionary Principle; Smart Meters-Firefighters; Letter from Susan Foster to San Diego Gas & Electric, California Public Utilities Commission; Nov. 8, 2011
421	10305-10348	Jul. 7, 2016	Environmental Health Trust	Precautionary Principle; Letter to the Montgomery County Board of Education Members, Theodora Scarato
422	10349-10352	Oct. 30, 2013	Diane Hickey	Precautionary Principle; Diane Hickey Comments
423	10353-10356	Sep. 3, 2013	Monnie Ramsell	Precautionary Principle; Monnie Ramsell Comments
424	10357-10409	Aug. 29, 2013	Kevin Kunze	Precautionary Principle; Kevin Kunze Comments
425	10410-10429	Feb. 6, 2013	Clara De La Torre	Precautionary Principle; Clara de La Torre Comments
426	10430-10431	Sep. 30, 2016	Center for Safer Wireless	Precautionary Principle; Center for Safer Wireless Comments

INDEX TO DEFERRED APPENDIX

427	10432-10440	Sep. 27, 2016	Gary C. Vesperman	Precautionary Principle; Possible Hazards of Cell Phones and Towers, Wi-Fi, Smart Meters, and Wireless Computers, Printers, Laptops, Mice, Keyboards, and Routers Book Three, Gary Vesperman Comments
428	10441-10443	Jul. 11, 2016	Cecelia Doucette	Precautionary Principle; Cecelia Doucette Comments
429	10444-10446	Aug. 31, 2016	Chuck Matzker	Precautionary Principle; Chuck Matzker Comments
430	10447-10460	Sep. 3, 2013	Diane Schou	Precautionary Principle; Dr. Diane Schou PhD, Dr. Bert Schou, PhD., Comments (letter sent to FCC's OET)
431	10461-10465	Sep. 3, 2013	Evelyn Savarin	Precautionary Principle; Evelyn Savarin Comments
432	10466-10468	Jun. 19, 2013	Jamie Lehman	Precautionary Principle; Jamie Lehman, Comments
433	10469-10470	Mar. 7, 2013	Marlene Brenhouse	Precautionary Principle; Marlene Brenhouse, Comments
434	10471-10474	Jul. 11, 2016	Lynn Beiber	Precautionary Principle; Lynn Beiber Comments
435	10475-10489	Sep. 2, 2013	Kevin Mottus	Precautionary Principle; Kevin Mottus Comments
436	10490-10491	Jul.13, 2016	Mary Paul	Precautionary Principle; Mary Paul, Comments
437	10492-10493	Jul. 11, 2016	Stephanie McCarter	Precautionary Principle; Stephanie McCarter Comments

INDEX TO DEFERRED APPENDIX

438	10494-10496	Feb. 4, 2013	Rebecca Morr	Precautionary Principle; Rebecca Morr Comments
439	10497-10505	Feb. 3, 2013	Nancy Baer	Precautionary Principle; Nancy Baer Comments
440	10506-10507	Sep. 2, 2013	Holly LeGros	Precautionary Principle; Holly LeGros Comments
441	10508-10509	Aug. 18, 2013	Loe Griffith	Precautionary Principle; Loe Griffith Comments
442	10510-10555	Nov. 18, 2013	EMR Policy Institute	EMR Policy Institute Reply Comments
443	10566-10572	Sep. 3, 2013	Leslee Cooper	Leslee Cooper Comments

Prenatal & Children; “Cell Phones & WiFi –
Are Children, Fetuses and Fertility at Risk?; 2013

Audio and Summary, Children's Health Expert Panel June 2013:

"Cell Phones & WiFi – Are Children, Fetuses and Fertility at Risk?"

Listen to the Audio Recording https://vimeo.com/73165877
Panelist Bios: http://electromagnetichealth.org/electromagnetic-health-blog/ct-childrens-health-panel/#panelists

Dedication to Ronald Herberman, MD

The program June 28, 2013 was dedicated to the late Ronald B. Herberman, Founding Director of the University of Pittsburgh Cancer Institute, Vice Chancellor of Cancer Research at University of Pittsburgh and the first head of an NCI funded cancer center to speak out on the risks from cell phones. He issued a warning of these risks to his 3,000 employees, addressed Congress, and, regarding inaccurate media reporting on cell phone radiation health risks in the *Economist*, Dr. Herberman said:

"A disservice has been done in inaccurately depicting the body of science, which actually indicates that there ARE biological effects from the radiation emitted by wireless devices, including damage to DNA, and evidence for increased risk of cancer and other substantial health consequences…The public the world over has been misled by this reporting."

May we all find within us the courage Dr. Braverman repeatedly exhibited during his life.

***

Conference Highlights: Discussion of Key Evidence EMFs Negatively Impact Children, Fetuses and Fertility

The panel presented a wide range of scientific evidence that electromagnetic radiation of the kind emitted by portable phones, Wi-Fi routers, baby monitors, Bluetooth earpieces, towers, antennas, smart boards, smart meters, Google glass and other devices is adversely affecting people across the globe, and especially children. This radiation may be 'non-thermal', but has clear and indisputable biological and health effects.

DNA is being damaged, and natural repair processes impaired, in this unnatural bath of radiation. Children are especially vulnerable to DNA effects due to the rapid growth and development of cells, as well as a longer lifetime of exposure. All frequencies react similarly with DNA, whether higher frequency or lower frequency. Some are faster, some are slower, but the effects are happening all the same. Cancer is believed to result from changes in DNA. DNA's coil of coil structure makes it exquisitely sensitive to EMF, more than other tissue in the body. The long-term impact for our species is unknown.

An increasing number of people listen, learn and think better in electromagnetically clean environments. The audience was asked to turn off their cell phones and wireless devices for this reason.

Cell phones, tablets and other wireless devices also have batteries that emit *lower frequency forms* of radiation—and these, too, along with RF and microwaves, have consequences, such as increased risk for childhood asthma and obesity when exposed in utero.

Impacts of electromagnetic fields on children*:

⇒Research shows radiation emitted by cell phones and WiFi impacts children's development *in utero*, their cognitive function, attention, memory, perception, learning capacity, energy, emotions and social skills.

⇒There is also diminished reaction time, decreased motor function, increased distraction, hyperactivity, and inability to focus on complex and long-term tasks.

⇒Cellular devices can lead to a heightened sense of anxiety in children, to isolation, and feelings of psychological and physical dependency.

⇒There are now 9 types of cancer linked to cell phone use:

1. Glioma (Brain Cancer)
2. Acoustic Neuroma (tumor on acoustic nerve)
3. Meningioma (tumor of the meninges)
4. Salivary Gland cancer (parotid gland in cheek)
5. Eye Cancer
6. Testicular Cancer
7. Leukemia
8. Thyroid Cancer
9. Breast Cancer

⇒There is a direct relationship between duration of cell phone use and sperm count decline. Sperm count is reduced by half in men who carry cell phones in their pants pockets for four hours per day. The motility of the sperm is also impaired. The testicular barrier, that protects sperm, is the most sensitive of tissues in the body, and is 100x more absorbent. Besides sperm count and function, the mitochondrial DNA of sperm are damaged 3x more if exposed to cell phone radiation.

⇒DNA mutations have been linked more to damage on the male side in research from Iceland (http://www.nature.com/news/fathers-bequeath-more-mutations-as-they-age-1.11247), the assumption being that male sperm is more vulnerable than female eggs, which are more protected. Mutations increase with the age of the father, and more autism and schizophrenia increase with the age of the father.

⇒WiFi in homes depletes melatonin and leads to poor sleep quality and difficulty falling asleep.

⇒Use of wireless devices after lights out has been associated with children's mental health risks and suicide.

⇒Some of the most profound effects in children from *in utero* EMF exposure are emotional and behavioral.

⇒Online time, particularly multi-tasking in young children, has been linked with a chronically distracted view of the world (http://paw.princeton.edu/issues/2013/04/03/pages/3052/index.xml) preventing learning critical social, emotional and relational skills.

⇒There is imbalanced development of the right and left hemispheres of the brain, resulting in children having impaired ability to remember basic things, to use handwriting, or to feel empathy. There is a physiological as well as psychological addiction that is taking place.

Think about what it would be like to have an entire generation that has not developed the capacity for empathy."

—Devra Lee Davis, PhD MPH, Environmental Health Trust

⇒ *Children are beginning to show signs of dementia, where they cannot remember basic things, a global phenomenon now being called "Digital Dementia", (http://www.telegraph.co.uk/news/worldnews/asia/southkorea/10138403/Surge-in-digital-dementia.html) believed to potentially be irreversible. There are hundreds of digital detox camps in China and S. Korea; the first U.S. camp (http://campgrounded.org/) opened in Northern California this year.*

Devra Davis, PhD,
Environmental Health Trust
Watch Video: vimeo.com/71749330

⇒*Dr. Taylor summarized his recent study (http://www.yalemedicalgroup.org/cellphonestudy2012) at Yale University: A standard cell phone with a SAR rating of 1.6W/kg was placed atop the cages of pregnant mice for the duration of their pregnancy. Their offspring showed hyperactivity, diminished memory, apathy, impulsiveness, and other behaviors, compared to unexposed controls, mirroring children with ADHD. The severity of the effect depended on the length of exposure.*

Hugh Taylor, MD,
Yale University
Watch Video: vimeo.com/73431739

⇒*Dr. Taylor said the incidence of ADHD in the U.S. is on the rise (3-5% of school aged children or 2mm children have ADHD) and the growth parallels the increased use of cell phones.*

⇒*Besides observing behaviors in the mice, the Yale researchers also measured electrical activity in the brain of the exposed and unexposed mice. They found the mice that had been exposed briefly in utero had changes to the electrical signaling processes in the brain as adults. Note, the mice had only been exposed during pregnancy, not subsequently, but the brain function was "permanently altered". There appears to have been a dose-response relationship, where the longer the mice had been exposed per day during the study the greater the changes in brain function. Continuous exposure throughout pregnancy was much more dangerous than briefer exposures.*

⇒ *Dr. Taylor reminded the audience that while we don't think of ourselves as being on the cell phone 24 hours a day, the cell phone is still emitting radiation 24/7 and impacting us if it is turned on and near us, day or night. "It's not talking on the phone that matters, it's any time the phone is turned on", he said. Every 900 milliseconds, whether you are using the phone or not, your cell phone has a*

spike in radiation because it is looking for a signal from the tower, according to Dr. Davis.

⇒Researchers at UCLA (http://www.ncbi.nlm.nih.gov/pubmed/18467962) found that children of mothers who used cell phones most frequently during pregnancy showed nearly a two-fold increase in behavioral and emotional problems and hyperactivity by the time they reached school age. Dr. Hugh Taylor stated:

> ***"When you combine data like this—studies that show there is in fact an association in humans, with our studies in animals—it is clearly cause and effect."***

⇒Wi-Fi in schools is an 'enormous problem'. Some schools install massive, industrial strength routers right next to where children sit. Symptoms reported by children who sit near Wi-Fi routers include nausea, headaches, blurred vision, and poor sleep. The Israeli Health Ministry issued a report recommending against Wi-Fi in schools because there is simply no information about the effects of this type of chronic exposure.

⇒Russians caused the same EHS symptoms in the U.S. Embassy in cold war. Symptoms of electrohypersensitivity in WIFi environments—of fatigue, irritability, concentration difficulty—are the same symptoms experienced by US Embassy personnel in Moscow in the cold war, that came to be known as microwave syndrome (or radiowave sickness).

⇒There are reports of children dropping dead in Canada, or needing to wear pacemakers, after Wi-Fi installation in their schools.

⇒Dr. Blank presented a simple study done by Danish high school girls wanting to study effects of WiFi. They took cress cells and exposed half to WiFi for 12 days. At left are the unexposed and exposed cress cells, the effects of WiFi on this plant having been made clear.

⇒Turkish scientists recently discovered that mice exposed to cell phone radiation produced offspring with smaller brains, and more brain, liver, and eye damage. The Turkish government is launching a major campaign to raise awareness about cell phone radiation safety specifically geared towards pregnant women and young men interested in fathering healthy children.

⇒Prenatal exposure results in fewer cells in the hippocampus of the brain, the area we need for thinking, reasoning, judgment and significantly impairs the development of neurons in the brain.

⇒There is also irreversible DNA damage occurring from these devices, which effects the functioning of the child's body, and the quality of the genes they then pass on to future generations. Human cells, like all matter, are made up of charged particles, and these particles respond to EMFs. DNA has many different lengths and responds differently to various radiation frequencies—like different length antennas—and many effects are irreversible. DNA damage and mutations can cause cancer and other illnesses, but it can take years to detect symptoms.

"The range of frequencies used today can cause damage to DNA, at levels that are currently being used."

—Martin Blank, PhD, Special Lecturer and Retired Associate Professor of Physiology and Cellular Biophysics, Columbia University

⇒Fetal effects from cellphone and wireless include faster heart rates, genetic changes, altered brain development, and increased behavioral and emotional problems after birth.

⇒The strongest evidence for EMF effects are the science showing the connection between cell phone use and brain cancer (Hardell 2008, Kundi 2008), according to Dr. Carpenter. *The latency period between cell phone use and brain cancer is thought to be 20 to 30 years. Brain cancer rates are double for people who've been using cell phones for 10 years or more, appearing on the side of the head where they hold their phones, and risks are 5x greater for children using cell phones under the age of 20 than those over the age of 50.*

⇒Because children's nervous systems are still developing, synapses and myelin are being laid down continuously. For the body to create proteins, it must have correct DNA coding. EMFs break DNA apart, resulting in bad coding and mutations that result in poor brain function. Teenagers and children using cell phones before the myelination process is completed in the 20s are having a "whopping impact" on their brains.

⇒There is some evidence that DNA mutations resulting from radiofrequency signals are part of what's driving today's increased autism and schizophrenia rates. The evidence was summarized in December in the landmark BioInitiative Report 2012 by Harvard Professor, Dr. Martha Herbert, MD who runs the Transcend Research Lab at Mass General.

Dr. Herbert stated:

EMF/RFR from wifi and cell towers can exert a disorganizing effect on the ability to learn and remember, and can also be destabilizing to immune and metabolic function. This will make it harder for some children to learn, particularly those who are already having problems in the first place.

"Powerful industrial entities have a vested interest in leading the public to believe that EMF/RFR, which we cannot see, taste or touch, is harmless, <u>but this is not true</u>."

⇒***Radio towers, not just cell towers, are also a factor****. Based on 50 years of data, the closer a child lives to a radio tower, the higher his or her risk for developing cancer. The standard for "safe" power density remains 1,000 times too high. A 6x risk of cancer is still considered 'safe'.*

Politics of EMF Science

Martin Blank, PhD,
Columbia University
Watch Video: vimeo.com/71837266

No more research is needed in order to say with certainty that these effects are real, and there is sufficient cause to take action now to protect adults and children. *More research is desirable to better understand certain connections, and to continue looking at the long-term trends with epidemiology, but there is sufficient scientific evidence today on which to take precautionary steps to minimize this radiation in our lives.*

Regulatory bodies have allowed a trillion dollar wireless industry to emerge without pre-market health testing or post-market health surveillance.

A whole generation of people has been unaware of the risks of wireless radiation, and have not been taking precautions*. This is why public health officials are so concerned. There is already evidence that exposure to radiofrequency radiation in excess leads to disease. And exposures have grown dramatically in the last few years.*

Frank Clegg,
Canadians 4 Safe Technology
Watch Video: vimeo.com/71996834

Our grandchildren and children are "being used as lab rats in an experiment with no controls*….that's what we are doing with cell phone and wireless radiation with our children today."—Devra Davis, PhD, MPH. Environmental Health Trust*

Scientists who expose the truth about the risks from electromagnetic fields are intimidated and attacked and their careers jeopardized. *Industry-associated science is also designed to underestimate risks, thereby refuting the independent science and 'Manufacturing Doubt'. Esteemed scientists are sometimes finding it hard to publish.*

Just as Bill Moyers recently described was the case with suppression of evidence about lead ("The Toxic Politics of Science", *http://billmoyers.com/tag/lead-wars-the-politics-of-science-and-the-fate-of-americas-children/****), the wireless industry behaves as if risks from cell phones and wireless devices and infrastructure is 'a PR problem, not a public health problem'.***

The FCC has inadequate exposure guidelines. *US standards for radiofrequency/microwave exposure are based on an outdated, erroneous assumption that EMFs have no biological effects unless they cause tissue heating, like a high powered microwave oven heating your potato. Science has disproven this myth. The exposure guidelines fail to protect about 97 percent of the population, most especially children.*

> ***"The cell phone standards we use today for the 6.5 billion cell phones in the world were set 17 years ago and have never been updated, despite the fact that the users and uses of cell phones are very different now. And they've never been tested for their safety around children…We're in the midst of a huge experiment on ourselves and on our children"***
>
> ***—Devra Lee Davis, PhD, MPH, cancer epidemiologist and toxicologist, President of Environmental Health Trust, and author of Disconnect: The Truth About Cell Phone Radiation, What the Industry Is Doing to Hide It, and How to Protect Your Family***

Lower power towers and devices are possible, though instead power levels are being continually increased. *Cell phones and cell towers can be made safer, by using far less power. Also, most towers emit far more radiation than they're supposed to.*

Many countries are issuing advisories: *Australia advises limiting children's exposure to cell phones; Belgium has banned sales of cell phones for use by children under age 7; Turkey has banned ads targeting sales to children. The French National Assembly has banned WiFi in schools. Italy had a Supreme Court ruling in favor of a man who claimed his tumor was from cell phone use. A region of India, Rajasthan, has banned cell towers near schools, and won a court battle to defeat industries opposition. Standards in the Eastern block are 1,000 times stricter.*

"It may take some sort of catastrophe to get people's attention."*—Frank Clegg, former president of Microsoft Canada and founder of Canadians 4 Safe Technology, a member of the audience who later joined the panel to share his perspective.*

Several panel members compared the current situation where health risks of cell phone and wireless radiation are being downplayed, and the science suppressed, to other well-known public health scandals driven by commercial interests, *such as tobacco, lead, asbestos, DDT, Bisphenyl A, silica, vinyl chloride, PCBs, GMOs, pesticides in food, fracking, the neionicotinoid chemicals impacting bees.*

Safety Recommendations

- ***Extreme caution was advised for pregnant women or women hoping to conceive due to the profound long-term impact of environmental factors.*** *"A lot of who we are right now has to do with what our mothers did when they were pregnant and what type of exposures they had."—Hugh Taylor, MD, Chairman of Obstetrics and Gynecology and Reproductive Sciences, Yale University. As with DES and many other toxic substances, he said, the effects from exposure to the fetus may not appear for a generation.*
- ***Children should not be playing with radiating cell phones.*** *Young children should not be using cell phones, except in an emergency. If your child wants to play with the device, disconnect it from Wi-Fi and Internet, and put it in "airplane mode."*
- ***Limit or eliminate WiFi exposures.*** *If you have Wi-Fi, get rid of it if you can. If you can't, make sure your router is not in a high use area. Keep it turned it off as much as possible, or put it on a timer.*
- ***Schools should not have WiFi.*** *Panelists strongly opposed the installation of Wi-Fi in schools. Cabled/wired connections do not have the same risks.*
- ***Resume using landline phones whenever possible.*** *Get rid of your portable phone and use a landline instead. If you have a portable phone, don't sleep with it in your bedroom.*
- ***Keep your cell phone away from your body.*** *If you have a cell phone, keep it away from your body, as opposed to in your pocket or on your belt. If you're pregnant, keep it away from your belly. Keep your cell at the other end of the room, or on the seat of the car. Use texting more than talking. Special cell phone cases are available that filter out a significant portion of the radiation, but not all. Many metal cases can actually magnify radiation.*
- ***Use a wired earpiece with cell phones.***
- ***Caution about using cell phones in cars.*** *Signals bounce around inside your vehicle—and your head is the antenna.*
- ***Opt-out of new utility meters called 'smart meters'.*** *When possible, prevent smart meters from being installed in your home.*
- ***Never use wireless baby monitors.*** *Avoid the use of baby monitors as they all operate on microwave frequency.*
- ***Know your exposures.*** *For about $500, you or your community can purchase a meter (http://emfsafetystore.com/) with which to measure the EMF in any particular area—homes, schools, churches, etc.*
- ***EMF free zones are needed for pregnant women and children.*** *"Wi-Fi free" or "low Wi-Fi" zones should be designated for pregnant women and children, and others who are particularly sensitive to EMFs. The same applies in schools.*
- ***We need to be tracking biological effects****. "We need to seriously begin tracking the biological effects of EMFs…We need to be monitoring our children's*

health routinely. We have to train people how to do the research, and we have to invest in the research that's not being done."—Devra Lee Davis, PhD MPH

- ***We must take precaution.*** *"The precautionary principle is in order here—certain precautions should be taken as a result of the risk that's been identified. That's the reason we have seat belts in cars… not because every car is going to crash, but because we want to minimize the damage when they do."—Martin Blank, PhD*
- ***A one-dollar fee has been proposed on the sale of all cell phones as a means of generating revenue for research and education.*** *Over several years, such a levy would generate billions of dollars to finalize any unanswered questions about risks.*
- ***Industry must become engaged.*** *Strategies must be introduced to get industry involved, such as providing incentives or rewards for safer technology, or even amnesty. If all else fails, lawsuits, some of which are in the works, will get their attention.*
- ***FCC safety guidelines must be updated.*** *Outdated, unrealistic safety guidelines must be replaced with new ones that reflect modern science, such as those suggested in the BioInitiative Report 2012 (http://www.bioinitiative.org/).*
- ***Support labeling laws*** *requiring cell phone manufacturers to list radiation levels in an obvious place on the packaging and at the retailer.*
- ***Educated parents need to become involved, especially to protect our children.*** *Contact www.ElectromagneticHealth.org or www.EnvronmentalHealthTrust.org to learn how your can become involved in raising awareness on this important children's health issue, or by funding research, media communications and support for local communities. Keep abreast on this subject going forward as it related to children, fetuses and schools at Campaign for Radiation Free Schools (https://www.facebook.com/login.php?next=https%3A%2F%2Fwww.facebook.com%2Fgroups%2F110896245588878%2F) on Facebook.*
- ***Finding the Political Will.***

> ***"Find the place within that wants the truth about the degradation of our health and children's health to be known, that wants the deeply held value for health, and for true caring, that we all certainly share, to be at the core of our society, guiding our representatives in Congress, as well as the media."***

—Camilla Rees, MBA, Founder, ElectromagneticHealth.org, co-author "Public Health SOS: The Shadow Side of the Wireless Revolution" and organizer of the Children's Health Expert Forum "Cell Phones & WiFi—Are Children, Fetuses and Fertility at Risk?"

**** For References see:***

- ***"Mobile Phone Health Risks: The Case for Action to Protect Children"*** *(http://www.mobilewise.org/) Mobilewise, November 2011*
- ***Bioinitiative Report 2012, Section on Autism (http://electromagnetichealth.org/electromagnetic-health-blog/herbert-lausd/)*** *Martha Herbert, MD, Harvard University; Transcend Research Laboratory at Massachusetts General (autism research)*
- *"**Cell Phones: Technology, Exposures, Health Effects**," (http://www.ehhi.org/reports/cellphones/) John Wargo, PhD, and Hugh S Taylor, MD, Yale University, Environment & Human Health, Inc. December 2012*
- ***The Toxic Politics of Science**, (http://billmoyers.com/tag/lead-wars-the-politics-of-science-and-the-fate-of-americas-children/) Moyers & Co.*
- ***Campaign for Radiation Free Schools (Facebook)*** *(https://www.facebook.com/groups/110896245588878/)*
- ***Letter to Parents on Fertility and Other Risks to Children from Wireless Technologies** (http://electromagnetichealth.org/electromagnetic-health-blog/letter-to-parents/), by Camilla Rees (Including Research Bibliography)*
- ***Clifford Nass, PhD, Thomas M. Storke Professor at Stanford University and director of the Communication between Humans and Interactive Media (CHIMe) Lab.*** *(http://paw.princeton.edu/issues/2013/04/03/pages/3052/index.xml)*
- ***ElectromagneticHealth.org's Recommended EMF Books on Amazon*** *(http://astore.amazon.com/bescom08-20)*
- ***Remediation Resources (meters, shielding materials, etc.):*** *www.EMFSafetyStore.com*

Media: Please contact Emily@ElectromagneticHealth.org.

To be notified when more content becomes available, please register here: *http://electromagnetichealth.org/electromagnetic-health-blog/summary-and-audio/#register*

Prenatal & Children; Safe Schools 2012, Medical and Scientific Experts Call for Safe Technologies in Schools

Safe Schools

2012

Healthy Schools

Safe Schools

Health Promoting Schools

Proactive Safeguarding

Healthy Development

Optimised Learning

Medical and Scientific Experts Call for Safe Technologies in Schools

Medical Associations, medical doctors and leading scientists call for safe technologies in schools

Introduction

More[1] Medical Associations, medical doctors and scientists, many of whom work on the biological effects of wireless technologies, have expressed their concerns about the safety of wireless devices for schools. They are asking for wired information and communication technologies to be used in order to safeguard[2] children and young people, protect and promote healthy development and maximise learning and achievement.

These experts do not agree with the health protection agencies which currently support or allow the use of microwave, radiofrequency-emitting technologies by children and young people in schools.

Other authorities have also called for the protection of children from wireless technologies.

- Council of Europe: Mobile phone use by pupils in schools to be strictly regulated and wired internet connections to be preferred (Resolution 1815, 2011[3]).
- World Health Organization's International Agency for Research on Cancer (IARC) classified radiofrequency radiation as a possible human carcinogen, class 2B (2011)[4].
- UK Trades Union Congress (TUC): Caution should be taken to prevent exposure to Class 2B carcinogens in the workplace[5].
- European Environment Agency: All reasonable measures to be taken to reduce exposures to electromagnetic fields, especially radiofrequencies from mobile phones and particularly the exposures to children and young adults. Current exposure limits to be reconsidered[6].
- International Commission for Electromagnetic Safety (ICEMS): Strongly advise limited use of cell phones, and other similar devices, by young children and teenage*rs*[7].
- Russian National Committee on Non-Ionizing Radiation Protection have recommended the use of wired networks in schools and educational institutions, rather than wireless broadband systems, including Wi-Fi[8]. *"It is our professional obligation not to damage the children's health by inactivity"*[9]**.**
- German Government and Israeli Parliament recommended wired computer networks for schools or workplaces[10,11].
- Several countries have advised children and young people to limit their use of mobile/smart/cell phones[1].

This document serves to inform schools, Governing Bodies, Academy Trusts, School Boards, Education Authorities, teachers and parents of the professional, medical and scientific concerns about children using wireless technologies in schools. The information can be used to implement safe school policies, practices and guidance in order to safeguard the health and development of children and young people and to aid cognitive abilities, learning and achievement.

Contents

Grateful appreciation is given to all those who have offered comments for this document and helped in its preparation.

Available electronically at: http://www.wifiinschools.org.uk/resources/safeschools2012.pdf

June 2012. To contribute to a future edition, please contact:

E-mail: contact@wifiinschools.org.uk, Address: BM Wifiinschools.org.uk, London, WC1N 3XX.

Medical Associations

Dr Gerd Oberfeld, MD, Public Health Department, Salzburg, Austria, on behalf of the Austrian Medical Association.

Schools should provide the best possible learning environments. In this context low noise levels, good air quality and low radiofrequency / microwave radiation are crucial. Wi-Fi environments will lead to high microwave exposure for students and teachers which might increase the burden of oxidative stress. Oxidative stress might slow down the energy production especially in brain cells and may lead e.g. to concentration difficulties and memory problems in certain individuals. The Austrian Medical Association recommends Wi-Fi free school environments.

The American Academy of Environmental Medicine

The Board of Officers and Directors: Dr Alvis L. Barrier, MD, FAAOA; Dr Amy Dean, DO; Dr Charles L. Crist, MD; Dr James W. Willoughby, II, DO; Dr Robin Bernhoft, MD; Dr Gary R. Oberg, MD, FAAEM; Dr Craig Bass, MD; Dr Stephen Genius, MD, FRCSC, DABOG, FAAEM, DABEM; Dr Martha Grout, MD, MD(H); Dr W. Alan Ingram, MD; Dr Janette Hope, MD; Dr Derek Lang, DO; Dr Glen A. Toth, MD; Dr Ty Vincent, MD.

The Board of the American Academy of Environmental Medicine approved the following statement on Wi-Fi in schools on 9th June 2012:

Adverse health effects, such as learning disabilities, altered immune responses, headaches, etc. from wireless radio frequency fields do exist and are well documented in the scientific literature. Safer technology, such as using hard-wiring, must be seriously considered in schools for the safety of those susceptible individuals who may be affected by this phenomenon.

January 2012:

The Board of the American Academy of Environmental Medicine opposes the installation of wireless "smart meters" in homes and schools based on a scientific assessment of the current medical literature (references available on request). Chronic exposure to wireless radiofrequency radiation is a preventable environmental hazard that is sufficiently well documented to warrant immediate preventative public health action.

The Board of the American Academy of Environmental Medicine also wishes to note that the US NIEHS National Toxicology Program in 1999 cited radiofrequency (RF) *radiation as a potential carcinogen. Existing safety limits for pulsed RF were termed "not protective of public health" by the Radiofrequency Interagency Working Group (a federal interagency working group including the FDA, FCC, OSHA, the EPA and others)* (From AAEM Letter, January 2012, http://wifiinschools.org.uk/resources/AAEM.pdf).

The AAEM asks for:

- *Use of safer technology, including for "Smart Meters", such as hard-wiring, fiber optics or other non-harmful methods of data transmission.*
- *Independent studies to further understand the health effects of electromagnetic and radiofrequency exposures.*
- *Understanding and control of this electrical environmental bombardment for the protection of society.*

(For full list, see: http://aaemonline.org/pressadvisoryemf.pdf; AAEM Position Statement: http://aaemonline.org/emf_rf_position.html). References from the AAEM statements below can be found in: http://aaemonline.org/pressadvisoryemf.pdf.

The AAEM Position Statement on electromagnetic fields includes:

Multiple studies correlate radiofrequency exposure with diseases such as cancer, neurological disease, reproductive disorders, immune dysfunction, and electromagnetic hypersensitivity.

Arguments are made with respect to radiofrequency exposure from Wi-Fi, cell towers and smart meters that due to the distance, exposure to these wavelengths are negligible (2). However, many in vitro, in vivo and epidemiological studies demonstrate that significant harmful biological effects occur from non-thermal radiofrequency exposure and satisfy Hill's criteria of causality (3). Genetic damage, reproductive defects, cancer, neurological degeneration and nervous system dysfunction, immune system dysfunction, cognitive effects, protein and peptide damage, kidney damage and developmental effects have all been reported in the peer-reviewed scientific literature.

The fact that radiofrequency exposure causes neurological damage has been documented repeatedly. Increased blood-brain barrier permeability and oxidative damage, which are associated with brain cancer and neurodegenerative diseases, have been found (4,7,15-17). Nittby et al. demonstrated a statistically significant dose-response effect between non-thermal radiofrequency exposure and occurrence of albumin across the blood-brain barrier (15). Changes associated with degenerative neurological diseases such as Alzheimer's, Parkinson's and Amyotrophic Lateral Sclerosis (ALS) have been reported (4,10). Other neurological and cognitive disorders such as headaches, dizziness, tremors, decreased memory and attention, autonomic nervous system dysfunction, decreased reaction times, sleep disturbances and visual disruptions have been reported to be statistically significant in multiple epidemiological studies with radiofrequency exposure occurring non-locally (18-21).

In an era when all society relies on the benefits of electronics, we must find ideas and technologies that do not disturb bodily function. It is clear that the human body uses electricity from the chemical bond to the nerve impulse and obviously this orderly sequence can be disturbed by an individual-specific electromagnetic frequency environment.

International Society of Doctors for the Environment (ISDE)

Irish Doctors Environmental Association (IDEA)

Both the International Society of Doctors for the Environment [ISDE] and the Irish Doctors Environmental Association [IDEA] have stated, the former by an ad hoc majority opinion of the Directing Board and the latter by unanimous decision of the Executive Committee, that there is sufficient scientific evidence to warrant more stringent controls on the level and distribution of electromagnetic radiation [EMR].

ISDE and IDEA recommendations (full list in Appendix 1):

- *Avoid Wi-Fi in home or work if possible, particularly in schools or hospitals.*
- *Use wired technology whenever possible.*
- *Measure the radiation levels at sites which are occupied for prolonged periods, particularly by infants or young children.*
- *Base stations should not be located on or near [500m] schools or hospitals.*

The Interphone Study organised by the International Agency for Research on Cancer [IARC] – a $20 million study in many countries over 5 years, presented partial results in 2011 of their analysis of 6,600 cancer cases in relation to cell phone use. The results were equivocal but IARC has since designated EMR as "possibly carcinogenic to humans" [Group 2B].

Attention deficit hyperactivity disorder [ADHD] is known to be increasing in prevalence by 3% per year in the USA for which there is no generally accepted explanation. There is evidence from an epidemiological study [Divan, H. et al Epidemiology 19 523-529] from 2008 indicating an association between maternal cell phone use and the prevalence of behavioural problems in children. This was supported by an experimental study in mice from Yale University which demonstrated neurobehavioural defects which persisted into adulthood and was shown to be due to dose-dependent altered neurodevelopmental programming [Aldad T. S. et al Mar 2012 www.nature.com/scientificreports].

Because of the potentially increased risks for the foetus, infants and young children due to their thinner more permeable skulls and developing systems, particularly the immune and neurological systems, based on the precautionary principal and on the mounting evidence for harm at the sub-cellular level, we recommend that EMR exposure should be kept to a minimum. The basic theory is that the younger they are the more likely they are to be damaged for the above reasons and also they will be exposed for a longer period over their lifetime on average.

The Parliamentary Assembly of the Council of Europe Resolution 1815 in 2011 made numerous specific recommendations relating to EMR, the basic message being to maintain radiation levels 'as low as reasonably achievable' [ALARA].

Dr P. Michael, April 2012

Interdisciplinary Society for Environmental Medicine (Interdisziplinäre Gesellschaft für Umweltmedizin e. V.), Germany.

In the Freiburger Appeal in 2002, medical doctors in Germany requested:

- *Ban on mobile telephone use and digital cordless (DECT) telephones in preschools and schools*.
- *Ban on mobile telephone use by small children and restrictions on use by adolescents.*
- *Education of the public, especially of mobile telephone users, regarding the health risks of electromagnetic fields.*
- (Appeal in full: www.planningsanity.co.uk/reports/md341.doc).

Swiss Doctors for Environmental Protection (Ärztinnen und Ärzte für Umweltschutz (AefU)).

The Swiss Doctors for Environmental Protection have not specifically mentioned schools, but have called for caution with respect to wireless technologies:

The International Agency for Research on Cancer (IARC) considers the waves emitted by wireless communication "possibly carcinogenic". According to the IARC, the risk of cancer for this type of radiation is thus similar to that of the insecticide DDT, rightly banned. Doctors for the Environment is concerned that the limit values expected to protect the Swiss population, notably vulnerable groups such as children and pregnant women, constitute insufficient protection. In a communication sent to the Federal Assembly, Doctors for the Environment thus requests strict application of the principle of precaution and – in view of the risk of cancer – lower limit values.

Children's rooms, housing, trams or offices are experiencing a growing exposure to radiation from diverse sources: baby monitors, mobile telephony, Wi-Fi, etc., yet more and more studies warn against the serious health consequences of electromagnetic pollution for human beings and animals.

Dr Peter Kälin, President, states *"From the medical point of view, it is urgent to apply the precautionary principle for mobile telephony, Wi-Fi, power lines, etc."* http://www.aefu.ch/typo3/fileadmin/user_upload/aefu-data/b_documents/Aktuell/M_120322_NIS.pdf

Scientists and Medical Doctors

Dr Igor Belyaev Dr.Sc., Head Research Scientist, Cancer Research Institute, Slovak Academy of Science, Slovak Republic; Associate Professor in Toxicological Genetics, Faculty of Natural Science, Stockholm University, Sweden.

To my opinion, which is based on 25-year research of non-thermal effects of microwaves, usage of Wi-Fi and cell/mobile/smart phones in the classroom should be either forbidden or reduced as much as possible. I believe that the majority of scientists with long lasting experience in this scientific field are of the same opinion. Several national authorities have already advised limiting usage of mobile communication by children. Please, see recent news from Israel by the link below http://www.haaretz.com/business/knesset-backs-bill-requiring-cell-phones-to-bear-health-hazard-warning-1.415677 *, recommendation of the RNCNIRP in the file attached* (Appendix 2) *and my recent review (Belyaev 2010)*[12]*.*

Professor Dr. Nesrin Seyhan, Medical Faculty and Chair of Biophysics Department, Gazi University, Turkey; WHO EMF International Advisory Committee; Panel Member NATO RTA Human Factors and Medicine.

Dr. Seyhan, founder of the Gazi Non-Ionizing Protection Center (GNRK), always opposes radiofrequency sources near schools. She believes that potential adverse health effects from the children's use of Wi-Fi and cell/mobile/smart phone would be greater than with respect to adults. She also recommends that children younger than 16-years-old should not have their own mobile phone. Please find her last publication attached[13]*.*

Professor Lukas H. Margaritis, PhD, Professor Emeritus of Cell Biology and Radiobiology, Dept of Cell Biology and Biophysics, University of Athens, Greece.

Having done experiments on cellular model systems we have found an effect from electromagnetic radiation of ordinary Wi-Fi. I have strongly suggested for years now that they should be used only if absolutely necessary in the home and not at all in schools. There is no reason for having Wi-Fi in schools since there is an alternative - wired connections which are safer and faster.

Dr Stelios A. Zinelis, BA, MD, Hellenic Cancer Society, Cefallonia, Greece

We should not subject and force electromagnetic radiation on school children. Technology can be applied by a wired connection. Effects of the electromagnetic radiation have been well documented and should not be ignored. The past has taught as many lessons, for example asbestos.

Dr Samuel Milham MD, MPH, Epidemiology and Public Health, Formerly Washington State Department of Health, USA.

Wireless technologies have no place in schools. I strongly recommend that where they exist, they be replaced by fiber-optic cable and hard wiring.

Professor Dr. Oleg Grigoriev, PhD, Director of the Russian Centre for Electromagnetic Safety and Vice-Chairman of the RCNIRP.
Professor Yury Grigoriev, Dr. of Medical Science, Chairman of the Russian National Committee on Non-Ionizing Radiation Protection (RCNIRP); member of International Advising Committee on WHO EMF Project.

Our Committee and I are personally against the use of Wi-Fi systems in schools. Professor Yury Grigoriev (chairman of the RCNIRP) has the same opinion. The reason is that it forms a very complex form of electromagnetic field, but in this case the probability of biological effect is higher than when the same total dose is created by one source of unmodulated electromagnetic field. This pattern is for non-thermal electromagnetic fields. There are very good studies that have shown that prolonged exposure to low-intensity radio waves in children disturbed cognitive function, and we trust this research.

RCNIRP recommendation about Wi-Fi in schools and educational institutions, June 2012: http://international-emf-alliance.org/images/pdf/RussCNIRP%20WiFi%2019-06-12.pdf.

Professor Dr. Alvaro Augusto A. de Salles, PhD, Electrical Engineering Department, Federal University of Rio Grande do Sul, Porto Alegre, Brazil.

I believe that responsible governments should act firmly to avoid the use of mobile/smart phones and Wi-Fi in schools.

The main reasons are due to the scientific evidence already available in the international literature (e.g., Bioinitiative report, Pathophysiology 2009, Interphone report, Hardell's group papers, etc) showing health risks even at low level exposure to the non-ionizing radiation (NIR), the 2011 IARC/WHO possible carcinogenic (2 B) classification of the NIR and because due to different reasons, the children are more susceptible to this radiation.

Then the "Precautionary Principle" should effectively be used in this subject and instead of wireless connection, other fixed connections such as twisted pairs, coaxial cables, optical fiber, etc should be available for each student, avoiding therefore exposure during several hours to the NIR.

If serious and responsible decisions are not taken in due time, the price in terms of future generations public health can be very high.

Dr Kevin O'Neill, FRCS (SN), Consultant Neurosurgeon, Charing Cross Hospital, London, UK.

Letter to the British Medical Journal[14]:

You reported (BMJ 2011;342:d3428) on the Council of Europe's recommendation that children be protected from the electro-magnetic radiation emitted by wireless equipment in schools. Since then, the International Agency for Research into Cancer (IARC) has classified such radiation as a possible carcinogen.

The evidence for children's particular vulnerability is accumulating. Most recently a study by the University of Orebro, published in the International Journal of Oncology (Int J Oncol. 2011 May;38(5):1465-74) found almost a fivefold increase of astrocytoma among subjects who started mobile phone use before the age of 20.

Since the Council of Europe has little influence over national health policy and the IARC classification will take time to translate into practical advice, we as medical practitioners and professional bodies have a role in ensuring timely action is taken to protect children. Previous public health threats (tobacco, asbestos, x-rays) indicate that the evidence of risk often increases as research progresses. Given a latency lag of up to 20 years for many tumours, we are in danger of repeating these public health disasters.

Dr David Carpenter, MD, Director Institute for Health and the Environment, University at Albany and Professor Environmental Health Sciences, School of Public Health, USA.

Chronic, such as all-day, school exposure, is more likely than short and intermittent exposure, such as cell phone use, to produce harmful health effects, and is likely to do so at lower exposure levels. Persons stationed close to school computers with WI-FI and especially those very near to any WI-FI infrastructure will receive considerably higher exposure than do others.

Exposure to high-frequency radiofrequency (RF) and microwave (MW) radiation and also the extreme low frequency (ELF) EM fields that accompany WI-FI exposure have been linked to a variety of adverse health outcomes. Some of the many adverse effects reported to be associated with and/or caused by ELF fields and/or RF/MW radiation include neurologic, endocrine, immune, cardiac, reproductive and other effects, including cancers. Human studies of comparable RF/MW radiation parameters show changes in brain function including memory loss, retarded learning, performance impairment in children, headaches and neurodegenerative conditions, melatonin suppression and sleep disorders, fatigue, hormonal imbalances, immune dysregulation such as allergic and inflammatory responses, cardiac and blood pressure problems, genotoxic effects like miscarriage, cancers such as childhood leukemia, childhood and adult brain tumors, and more.

Children are more vulnerable to RF/MW radiation because of the susceptibility of their developing nervous systems. RF/MW penetration is greater relative to head size in children, who have a greater absorption of RF/MW energy in the tissues of the head at WI-FI frequencies. Children are largely unable to remove themselves from exposures to harmful substances in their environments. Their exposure is involuntary. There is a major legal difference between an exposure that an individual chooses to accept and one that is forced upon a person, especially a dependent, who can do nothing about it. WI-FI must be banned from school deployment. http://www.magdahavas.com/wordpress/wp-content/uploads/2012/01/Amended-Declaration-of-Dr-David-Carpenter.pdf

Letter about Wi-Fi in schools: http://wifiinschools.org.uk/resources/Carpenter+letter+Feb2011.pdf.

Dr Martin Blank, Ph.D., Associate Professor of Physiology and Cellular Biophysics, College of Physicians and Surgeons, Columbia University, New York, USA.

Just because we allow microwaves, doesn't mean that Wi-Fi at the same frequency should be allowed into all classrooms.

There is now sufficient scientific data about the biological effects of electromagnetic fields (EMF), and in particular about radiofrequency (RF) radiation, to argue for adoption of precautionary measures. We can state unequivocally that EMF can cause single and double strand DNA breakage at exposure levels that are considered safe under the FCC guidelines in the USA.

EMF have been shown to cause other potentially harmful biological effects, such as leakage of the blood brain barrier that can lead to damage of neurons in the brain, increased micronuclei (DNA fragments) in human blood lymphocytes, all at EMF exposures well below the limits in the current FCC guidelines. Probably the most convincing evidence of potential harm comes from living cells themselves when they start to manufacture stress proteins upon exposure to EMF. The stress response occurs with a number of potentially harmful environmental factors, such as elevated temperature, changes in pH, toxic metals, etc. This means that when stress protein synthesis is stimulated by radiofrequency or power frequency EMF, the body is telling us in its own language that RF exposure is potentially harmful.

It is obvious that the safety standards must be revised downward to take into account the non-thermal as well as thermal biological responses that occur at much lower intensities. Since we cannot rely on the current standards, it is best to act according to the precautionary principle. The precautionary approach appears to be the most reasonable for those who must protect the health and welfare of the public and especially its most vulnerable members, children of school-age. (Letter, Appendix 3).

Dr Olle Johansson, Associate Professor, Karolinska Institute, Stockholm, and Professor, The Royal Institute of Technology, Stockholm, Sweden.

Wireless communication is now being implemented in our daily life in a very fast way. At the same time, it is becoming more and more obvious that the exposure to the electromagnetic fields used by these systems not only may induce acute thermal effects to living organisms, but also non-thermal effects, the latter often after longer exposures. This has been demonstrated in a very large number of studies and includes cellular DNA-damage, disruptions and alterations of cellular functions like increases in intracellular stimulatory pathways and calcium handling, disruption of tissue structures like the blood-brain barrier, impact on vessel and immune functions, association to cancer, and loss of fertility.

Wireless systems, such as Wi-Fi routers and cell/mobile/smart phones, cannot be regarded as safe in schools, but must be deemed highly hazardous and unsafe for the children as well as for the staff.

Dr Magda Havas, PhD, Associate Professor, Environmental and Resource Studies, Trent University, Ontario, Canada.

I am a scientist researching the adverse health outcomes of electromagnetic radiation exposure, including from sources such as WI-FI networks and cell towers. I conducted a study that showed immediate and dramatic changes in both heart rate and heart rate variability associated with microwave exposure to a frequency of 2.4 GHz at levels well below (0.5 percent) federal guidelines. The reactions include heart irregularities, a rapid heart rate, up-regulation of the sympathetic nervous system, and down-regulation of the parasympathetic nervous system.

It is important that children be exposed to the important education, life experiences, and social structures that public education offers, but they must not be risking their health to do so! Children must not be exposed to a constant background of pulsed microwave radiation from WI-FI (or other sources) while at school.

The Internet is an important learning device that should not be taken away. I simply urge that its access be made available through wires rather than Wi-Fi.
http://www.magdahavas.com/wordpress/wp-content/uploads/2012/01/Declaration-of-Dr.-Magda-Havas.pdf

Dr Erica Mallery-Blythe, BM, Emergency Room Registrar, Medical Advisor ES-UK

Radiofrequency radiation was classified last year (2011) as a class 2B carcinogen by the International Agency for Research on Cancer (IARC)/World Health Organization (WHO). This means that Global Health Authorities are concerned that this kind of radiation (used by many kinds of household wireless devices) may cause cancer. There are several convincing mechanisms via which cellular disruption is taking place and all bodily systems are potentially vulnerable. All persons should, in my opinion, take precaution to reduce their exposure to unnatural radiation, including that from non-ionizing, non-thermal sources such as cell phones, Wi-Fi routers, cordless landlines and many others. This advice is particularly important for parents and Education Authorities when creating home and school environments because children are more vulnerable to this kind of radiation.

Science has repeatedly and clearly demonstrated adverse effects of artificial electromagnetic fields on biological systems. It is far too late for timely intervention, but failure to act now with conviction and protect our children could lead to a national health disaster.

Professor Dr. Christos Georgiou, PhD, Professor of Biochemistry, University of Patras, Greece

Every child has the non-negotiable, obvious right to a healthy and safe school environment.

Governments and school boards can no longer trust the wireless communication industry's monotonous slogan that Wi-Fi and cell phones are safe. In May 2011, the World Health Organization (WHO) classified microwave radiation, emitted by such wireless devices, as a possible carcinogen. WHO could no longer ignore the scientific and social pressure from

numerous studies, which have shown that Wi-Fi/cell phone radiation penetrates the body, affects cell membranes, makes cells lose their ability to function properly over time, and disturbs the body's normal metabolism causing numerous abnormalities and diseases.

Children are especially vulnerable to microwave radiation because their nervous system and especially the brain are still developing. Moreover, their skulls are thinner and smaller than those of the adults, so the radiation penetrates their brains more freely and deeply.

Microwave radiation displays in children life threatening short and long term effects: the short term effects are experienced as headaches, dizziness, nausea, vertigo, fatigue, visual and auditory distortion (voices change volume, ringing ears), abnormal heart rates (racing heart rate or tachycardia, erratic heart rates), memory loss, attention deficit (trouble concentrating while in class), skin rash, hyperactivity, anxiety, autism, depression, night sweats, insomnia (microwaves affect melatonin levels), learning impairment, behavioural changes etc; the long term effects are expressed as stress, a weakened immune system, seizures, epilepsy, high blood pressure, brain damage, diabetes, fibromyalgia, infertility, birth defects, DNA damage, leukemia, cancer, etc.

Dr Isaac Jamieson, PhD, DIC RIBA DipAAS BSc (Hons) MInstP, Architect, Consultant and Environmental Scientist, UK.

Proactively addressing 'electromagnetic pollution' issues may significantly aid well-being and achievement in individual schools. It appears sensible for 'Health Promoting Schools', and other schools interested in the well-being of their staff and pupils to consider such matters. (Full Report in Appendix 4).

Professor Dr. Franz Adlkofer, MD, Chairman of Pandora - Foundation for Independent Research.

While the use of mobile phones is the result of people's free choice, their exposure to W-LAN and other wireless applications is mostly compulsory. Especially concerned are children in schools where this technology has been given preference to wired computers. Since our knowledge on possible adverse effects of radiofrequency electromagnetic fields is still rather poor, it is obvious that at present the biggest biophysical experiment of mankind is under way – with an uncertain outcome. In May 2011, the uncertainty has been strengthened by the International Agency for Research on Cancer (IARC) that classified radiofrequency electromagnetic fields as 'possibly carcinogenic to humans'. This decision was mainly based on the results of epidemiological studies that observed after long-term (>10 years) and intensive use of mobile phones an increased risk for brain tumours exactly at the side of the head at which the mobile phone was used. The results from animal experiments, although of minor significance, supported the decision. Yet, results from basic research that showed changes in structure and functions of genes in isolated human and animal cells as well as in living animals after exposure, and that would have given additional weight to the epidemiological

observations, were not taken into account. Had they been included in the evaluation, the classification would not have been 'possibly carcinogenic' but rather 'probably carcinogenic'.

The general public is confronted with two different views, one represented by politics and industry and one by the growing number of independent researchers. Ordinary people have either no idea of the probably adverse effects of radiofrequency radiation or have full confidence in the exposure limits that according to their governments reliably protect from any risk to the health. They do not know that the exposure limits are based on pseudo-science thought to create the necessary legal frame for a telecommunication industry that wants to make use of the new technology without being hampered by medical considerations.

For a medical doctor like me, the conclusion from the present state of knowledge must be that a precautionary approach is overdue and must not be delayed anymore. (Full Statement in Appendix 5).

Dr Vini G. Khurana, MBBS, BSc (Med), PhD, FRACS, Associate Professor of Neurosurgery, Australian National University Medical School; Currently Visiting Attending Neurosurgeon, Royal Melbourne Hospital.

The concerns raised regarding the unnecessary and prolonged exposure of children to near-field radiofrequency electromagnetic radiation (RF-EMR) from mobile phones, wireless laptops (on their laps), and nearby Wi-Fi transmitters in schools are shared by many.

A precautionary approach is realistically achieved without compromising convenience and safety. See for example: http://www.brain-surgery.us/brain_spine_health.html

There are good grounds for adopting such an approach in children, particularly in the context of the WHO's recent classification of RF-EMR as "possibly carcinogenic to humans", and the fact that children may be more susceptible to any adverse health effects of RF-EMR owing to their thinner scalp and skull, increased brain water content, lower brain volume, and rapidly developing neural connections.

Dr Annie Sasco, MD, PhD, Director, Epidemiology for Cancer Prevention, INSERM (Institut national de la santé et de la recherche médicale) Research Unit, School of Public Health, Victor-Segalen Bordeaux 2 Université, France. Formerly International Agency for Research on Cancer (IARC) Unit Chief of Epidemiology for Cancer Prevention.

If we want to wait for final proof, at least in terms of cancer, it may still take 20 years and the issue will become that we will not have unexposed population to act as control. We may never have the absolute final proof. But we have enough data to go ahead with a precautionary principle to avoid exposures (radiofrequencies) *which are unnecessary if our goal is to reduce somewhat the burden of cancer in the years to come and other chronic diseases.*

Dr Alfonso Balmori, PhD, Biologist, Researcher on effects of electromagnetic fields on wildlife, Valladolid, Spain.

The ongoing invasion of radiation caused by Wi-Fi transmitters and other radiofrequency sources represents a denial of scientific evidence and extreme myopia. It is absurd when cable can be used with much greater speeds that schools choose to do so by air. Moreover health must take priority over access to information. Wi-Fi systems are being senselessly installed, even for young children. Society is performing an extremely dangerous and suicidal experiment with them. In it are included not only the children of those who are convinced that electromagnetic radiation is harmful but also the children of the promoters of such systems, both politicians and those who work in the communications industry and also the scientists who deny the evidence. The problems of depression, attention deficit and insomnia in children are increasing worldwide at an alarming rate.

Dr Mae-Wan Ho, PhD, FRSA, Director of the Institute of Science in Society, London, UK.

It is very important for schools and other public places frequented by children to be free of Wi-Fi. The evidence on 'non-thermal' biological effects of very weak electromagnetic fields is now indisputable and children are many times more at risk than adults.

Dr Norbert Hankin, PhD, Environmental Scientist, Office of Radiation and Indoor Air, Environmental Protection Agency, USA.

The growing use of wireless communications by children and by schools will result in prolonged (possibly several hours per day), long-term exposure (12 or more years of exposure in classrooms connected to computer networks by wireless telecommunications) of developing children to low-intensity pulse modulated radiofrequency radiation.

Recent studies involving short-term exposures have demonstrated that subtle effects on brain functions can be produced by low-intensity pulse modulated radiofrequency radiation. Some research involving rodents has shown adverse effects on short-term and long-term memory. The concern is that if such effects may occur in young children, then even slight impairment of learning ability over years of education may negatively affect the quality of life that could be achieved by these individuals, when adults[15].

The individuals listed below signed the Porto Alegre Resolution in 2010, which stated:

We strongly recommend these precautionary practices:

1. Children under the age of 16 should not use mobile phones and cordless phones, except for emergency calls;

2. The licensing and/or use of Wi-Fi, WIMAX, or any other forms of wireless communications technology, indoors or outdoors, shall preferably not include siting or signal transmission in ... schools ... or any other buildings where people spend considerable time.

Franz Adlkofer, Prof. Dr. Med., Verum Foundation, Germany.
Carl Blackman, PhD., CFB, USA.
Martin Blank, PhD. Prof. Columbia Univ., USA.
Devra L. Davis, PhD , MPA , Founder, Environmental Health Trust, USA.
Om P. Gandhi, Sc.D. , Univ. of Utah, USA.
Michael Kundi, PhD. , Medical Univ. of Vienna, Austria.
Henry Lai, PhD., Univ. of Washington, USA.
Leif Salford, MD, PhD., Lund Univ., Sweden.
Carlos E. C. Abrahão, M.D. , Campinas, SP, Brazil.
Adilza C. Dode, M. Sc., MRE, MG, Brazil.
Claudio R. Fernández, M. Sc., IFSUL, Pelotas, RS, Brazil.
Robson Spinelli Gomes, Dr., MP/RJ, Brazil.
Sergio Koifman, M.D., ENSP/Fiocruz, RJ, Brazil.
Renato R. Lieber, Dr., UNESP, Guaratinguetá, SP, Brazil.
Alvaro A. de Salles, Ph.D., UFRGS, RS, Brazil.
Solange R. Schaffer, M.Sc., Fundacentro, SP, Brazil.
Helio A. da Silva, Dr., UFJF, MG, Brazil.
Francisco de A. Tejo, Dr. , UFCG, Pb, Brazil.
Geila R. Vieira, M.D., CGVS/SMS, P. Alegre, RS, Brazil.
Rodrigo Jaimes Abril, Vice Dean, Electrical Engineer, National University of Colombia, Bogota, Col.
Betânia Bussinger, M.D., Biological Effects of Non Ionizing Radiation, UFF, RJ, Brazil.
Simona Carrubba, PhD, Louisiana State Univ. Health Science Center, Shreveport, La, USA.
Claudio Gómez-Perretta, MD, PhD. Centro Investigación, Hospital Universitario La Fe,Valencia. Spain.
Christos Georgiou, PhD., ICEMS, Prof. Biochemistry, University of Patras, Greece.
Karl Braun-von Gladiß. Dr. med., Arzt für Allgemeinmedizin, Deutsch Evern, Germany.
Yury Grigoriev, Professor, Dr. of Medical Science, Chairman of Russian National Committee on Non-Ionizing Radiation Protection, Moscow (Russian Federation).
Magda Havas, PhD. Prof. Environmental Science, Trent University, Peterborough, Ontario, Canada.
Olle Johansson, Assoc. Prof., The Experimental. Dermatology Unit, Department of Neuroscience, Karolinska Institute; and Professor, The Royal Institute of Technology, Stockholm, Sweden.
Lukas H. Margaritis,Professor of Cell Biology and Radiobiology, Athens University, Greece.
L. Lloyd Morgan, Electronics Engineer (retired), USA.
Wilhelm Mosgoeller, MD, Prof. Medical University of Vienna, Austria.
Jerry L. Phillips, PhD. Prof. Dir. Science Learning Ctr. Univ. Colorado, Colorado Springs, USA.
Nesrin Seyhan, PhD., ICEMS, Prof. Medical Faculty of Gazi University, Chair, Biophysics Dept. Turkey Rep/WHO EMF IAC, Panel member, NATO RTO, HFM, Turkey.
David Servan-Schreiber, MD, PhD. Clinical Professor, Psychiatry, Univ. Pittsburgh USA.
Stanislaw Smigielski, MD, ICEMS, Military Institute of Hygiene & Epidemiology, Poland.
Stelios A Zinelis MD, ICEMS, Hellenic Cancer Society, Cefallonia, Greece.
Jose Maria Tiburcio Barroso, engineer, Niteroi, RJ, Brazil.
Elza Antonia Pereira Cunha Boiteux, Prof. Dra.,Faculdade de Direito, Universidade de São Paulo, BR.

Sergio A. Pereira De Borja, Prof. Direito Constituciona, PUC/RS e da Instituicones de Direito, UFRGS.
Elaine S. A. Cabral, M. Sc., Education, Environmental Law; member, Human Rights Commission - of Attorney Association-OAB, J. de Fora, MG, Brazil.
Bill Curry, PhD. Physics, ret. Argonne National Labs, Board Member, EMR Network, USA.
Adamantia F. Fragopoulou, B.Sc., M.Sc., Ph.D. Candidate, EMF Bioeffects, Athens Univ. Greece.
Cristiano M. Gallep, Prof. Dr., DTT, Unicamp, Brazil.
Carol C. Georges, PhD. Psychologist, Italy.
Andrew Goldsworthy BSc PhD, Lecturer in Biology (retired) Imperial College, London, UK.
Laura Elza L. F. Gomes. M.Sc., Prof. da Escola de Arquitetura e Urbanismo da UFF – Universidade - Federal Fluminense.
Sue Grey, LLB(Hons), BSc (Microbiology and Biochemistry), RSHDipPHI, New Zealand.
João Henrique C. Kanan, PhD, UFRGS, RS, Brazil.
Luiz Roberto Santos Moraes, Professor Titular em Saneamento, Universidade Federal da - Bahia, Brazil.
Daniel Oberhausen, Prof. Physics (retired), Association PRIARTÉM, France.
Fanny Helena Martins Salles, psychologist, public official, Prof. University of Bage, RS, Brazil.
Sarah J. Starkey, PhD. Neuroscientist, UK.
Alex W. Thomas, Ph.D, CIHR University-Industry, Chair, Bioelectromagnetics, Lawson Health Research - Institute, University of Western Ontario.
Casper Wickman, PhD, Chalmers University of Technology, Sweden.

Porto Alegre Resolution in full, with all signatures:
http://www.icems.eu/docs/resolutions/Porto_Alegre_Resolution.pdf

References

1 Wireless Technologies and Young People, A Resource for Schools, 2011. Wifiinschools.org.uk. http://wifiinschools.org.uk/resources/wireless+technologies+and+young+people+Oct2011.pdf

2 Safeguarding definition from 'Safeguarding in Schools: Best Practice', Ofsted, September 2011. Ref 100240. http://www.ofsted.gov.uk/resources/safeguarding-schools-best-practice

Protecting children and learners from maltreatment; preventing impairment of children's and learners' health or development; ensuring that children and learners are growing up in circumstances consistent with the provision of safe and effective care; undertaking that role so as to enable those children and learners to have optimum life chances and to enter adulthood successfully.

3 Parliamentary Assembly of the Council of Europe calls on governments to 'take all reasonable measures' to reduce exposure to electromagnetic fields; Resolution 1815, 27th May 2011. The potential dangers of electromagnetic fields and their effect on the environment. http://assembly.coe.int/ASP/NewsManager/EMB_NewsManagerView.asp?ID=6685&L=2; http://assembly.coe.int/Mainf.asp?link=/Documents/AdoptedText/ta11/eRES1815.htm

4 IARC classifies radiofrequency electromagnetic fields as possibly carcinogenic to humans. International Agency for Research on Cancer, World Health Organization, 31st May 2011.

http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf Lancet Oncology: http://www.thelancet.com/journals/lanonc/article/PIIS1470-2045(11)70147-4/fulltext

5 Occupational Cancer, A Workplace Guide. Trades Union Congress (TUC), UK; November 2008, Updated February 2012. http://www.tuc.org.uk/extras/occupationalcancer.pdf

6 Statement 15th September 2009, Professor Jacqueline McGlade, Director of the European Environment Agency. http://latelessons.ew.eea.europa.eu/fol572324/statements/Benefits_of_mobile_phones_and_potential_hazards_of_EMF.doc/download

7 International Commission for Electromagnetic Safety (ICEMS), Venice Resolution 6th June 2008 http://www.icems.eu/resolution.htm

8 Resolution of the Russian National Committee for Non-Ionizing Radiation Protection, 19th June 2012. Recommendations of the Russian National Committee on Non-Ionizing Radiation Protection of the necessity to regulate strictly the use of Wi-Fi in kindergartens and schools. http://international-emf-alliance.org/images/pdf/RussCNIRP%20WiFi%2019-06-12.pdf

9 Statement from the Russian National Committee for Non-Ionizing Protection, 14th April 2008. Children and mobile phones: The health of the following generations is in danger. http://www.radiationresearch.org/pdfs/rncnirp_children.pdf

10 Lower House of the German Parliament [Bundestag] printed matter 16/6117, 2007. Radiation exposure due to wireless Internet-Networks (WLAN). http://www.icems.eu/docs/deutscher_bundestag.pdf

11 Reducing exposure to electromagnetic radiation, Israel Environment and Health Committee 28th November 2010. http://translate.google.com/translate?js=n&prev=_t&hl=en&ie=UTF-8&layout=2&eotf=1&sl=iw&tl=en&u=http://www.ynet.co.il/articles/0,7340,L-3988033,00.html

12 Belyaev I., 2010. Dependence of non-thermal biological effects of microwaves on physical and biological variables: implications for reproducibility and safety standards. In: Giuliani L., Soffritti M., editors. European Journal of Oncology – Library, NON-THERMAL EFFECTS AND MECHANISMS OF INTERACTION BETWEEN ELECTROMAGNETIC FIELDS AND LIVING MATTER. An ICEMS Monograph Vol. 5. Bologna, Italy: RAMAZZINI INSTITUTE, http://www.icems.eu/papers.htm?f=/c/a/2009/12/15/MNHJ1B49KH.DTL; pp. 187-218.

13 Cam S. T. and Seyhan N. 2012. Single-strand DNA breaks in human hair root cells exposed to mobile phone radiation. International Journal of Radiation Biology 88(5):420-424. http://www.ncbi.nlm.nih.gov/pubmed/22348707

14 O'Neill K. S., 2011. British Medical Journal, 342:d3428. Protecting children from mobile radiation. In response to 'Radiation fears prompt possible restrictions on wi-fi and mobile phone use in schools.' http://www.bmj.com/rapid-response/2011/11/03/protecting-children-mobile-radiation

15 Norbert Hankin Quote, page 218, in: 'Cell Phones, Invisible hazards in a wireless age'. By Dr George Carlo and Martin Schram, 2001. Carroll and Graf Publishers, ISBN: 0-7867-0960-X.

Papers finding biological or health effects of Wi-Fi signals or Wi-Fi-enabled technologies can be found here: http://wifiinschools.org.uk/22.html

Appendix 1

Statement on Electromagnetic [radio frequency] Radiation [EMR] and Health Risks.

International Society of Doctors for the Environment [ISDE] and the Irish Doctors Environmental Association [IDEA].

Both the International Society of Doctors for the Environment [ISDE] and the Irish Doctors Environmental Association [IDEA] have stated, the former by an ad hoc majority opinion of the Directing Board and the latter by unanimous decision of the Executive Committee, that there is sufficient scientific evidence to warrant more stringent controls on the level and distribution of EMR.

The Interphone Study organised by the International Agency for Research on Cancer [IARC] – a $20 million study in many countries over 5 years, presented partial results in 2011 of their analysis of 6,600 cancer cases in relation to cellphone use. The results were equivocal but IARC has since designated EMR as "possibly carcinogenic to humans" [Group 2B].

ADHD is known to be increasing in prevalence by 3% per year in the USA for which there is no generally accepted explanation. There is evidence from an epidemiological study [Divan, H et al *Epidemiology 19 523-529*] from 2008 indicating an association between maternal cell phone use and the prevalence of behavioural problems in children. This was supported by an experimental study in mice from Yale University which demonstrated neurobehavioural defects which persisted into adulthood and was shown to be due to dose-dependent altered neurodevelopmental programming [Tamir S Aldad et al Mar 2012 www.nature.com/scientific reports

Because of the potentially increased risks for the foetus, infants and young children due to their thinner more permeable skulls and developing systems, particularly the immune and neurological systems, based on the precautionary principal and on the mounting evidence for harm at the sub-cellular level, we recommend that EMR exposure should be kept to a minimum. The basic theory is that the younger they are the more likely they are to be damaged for the above reasons and also they will be exposed for a longer period over their lifetime on average.

The Parliamentary Assembly of the Council of Europe Resolution 1815 in 2011 made numerous specific recommendations relating to EMR, the basic message being to maintain radiation levels 'as low as reasonably achievable' [ALARA].

Recommendations

Personal:

Avoid totally or minimise to essential usage below the age of 14 years

Use ‘hands free’ at all ages.

Minimise duration of calls.

Avoid having the phone on standby on your person, particularly adjacent to the gonads [testicles and ovaries] or heart.

Avoid using in a motor car or enclosed space.

Avoid use in pregnancy.

Use phone with the lowest Specific Absorption Ratio [SAR].

General:

Avoid living or working within 100m of a base station.

Avoid Wi-Fi in home or work if possible, particularly in schools or hospitals.

If Wi-Fi is present only switch it on when in use.

Measure the radiation levels at sites which are occupied for prolonged periods, particularly by infants or young children.

Base stations should not be located on or near [500m] schools or hospitals.

Use wired technology whenever possible.

Dr P. Michael May 2012

Appendix 2

Children and mobile phones: The Health of the Following Generations is in Danger.

Russian National Committee on Non-Ionizing Radiation Protection.

April 2008
(Page iv)

Russian National Committee on Non-Ionizing Radiation Protection

CHILDREN AND MOBILE PHONES:
THE HEALTH OF THE FOLLOWING GENERATIONS IS IN DANGER

Moscow, Russia *14 April 2008*

For the first time in history, we face a situation when most children and teenagers in the world are continuously exposed to the potentially adverse influence of the electromagnetic fields (EMF) from mobile phones.

Electromagnetic field is an important biotropic factor, affecting not just a human health in general, but also the processes of the higher nervous activity, including behavior and thinking. Radiation directly affects human brain when people use mobile phones.

Despite the recommendations, listed in the Sanitary Rules of the Ministry of Health, which insist that persons under 18 years should not use mobile phones (SanPiN 2.1.8/2.2.4.1190-03 point 6.9), children and teenagers became the target group for the marketing the mobile communications.

The current safety standards for exposure to microwaves from the mobile phones have been developed for the adults and don't consider the characteristic features of the children's organism. The WHO considers the protection of the children's health from possible negative influence of the EMF of the mobile phones as a highest priority task. This problem has also been confirmed by the Scientific Committee of the European Commission, by national authorities of the European and Asian countries, by participants of the International scientific conferences on biological effects of the EMF.

Potential risk for the children's health is very high:

- the absorption of the electromagnetic energy in a child's head is considerably higher than that in the head of an adult (children's brain has higher conductivity, smaller size, thin skull bones, smaller distance from the antenna etc.);
- children's organism has more sensitivity to the EMF, than the adult's;
- children's brain has higher sensitivity to the accumulation of the adverse effects under conditions of chronic exposure to the EMF;
- EMF affects the formation of the process of the higher nervous activity;
- today's children will spend essentially longer time using mobile phones, than today's adults will.

According to the opinion of the Russian National Committee on Non-Ionizing Radiation Protection, the following **health hazards** are likely to be faced by the children mobile phone users in the **nearest** future: disruption of memory, decline of attention, diminishing learning and cognitive abilities, increased irritability, sleep problems, increase in sensitivity to the stress, increased epileptic readiness.

Expected (possible) remote health risks: brain tumors, tumors of acoustical and vestibular nerves (in the age of 25-30 years), Alzheimer's disease, "got dementia", depressive syndrome, and the other types of degeneration of the nervous structures of the brain (in the age of 50 to 60).

The members of the Russian National Committee on Non-Ionizing Radiation Protection emphasize ultimate urgency to defend children's health from the influence of the EMF of the mobile communication systems. We appeal to the government authorities, to the entire society to pay closest attention to this coming threat and to take adequate measures in order to prevent negative consequences to the future generation's health.

The children using mobile communication are not able to realize that they subject their brain to the EMF radiation and their health – to the risk. We believe that this risk is not much lower than the risk to the children's health from tobacco or alcohol. It is our professional obligation not to let damage the children's health by inactivity.

On behalf of members of Russian National Committee on Non-Ionizing Radiation Protection

Chairman, professor

46, Zhivopisnaya Str., 123182 Moscow, RUSSIA
+7-499-193-0187 rcnirp@mail.ru

Appendix 3

Columbia University, College of Physicians and Surgeons

Department of Physiology and Cellular Biophysics Telephone: (212) 305-3644
630 West 168 Street Telefax: (212) 305-5775
New York, NY 10032 EMAIL: mb32@columbia.edu

May 22, 2009

Ms. Julie Korenstein
Board Member
Los Angeles Unified School District
Board of Education
333 South Beaudry Avenue, 24th Floor
Los Angeles, CA 90017

Re: Health effects of cell tower radiation

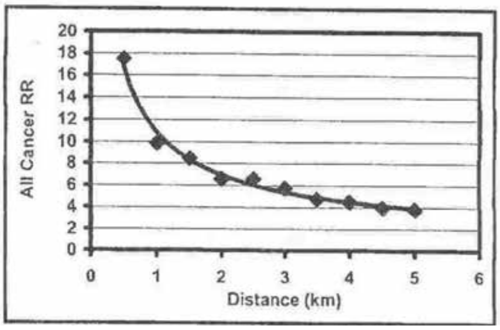
Dear Ms. Korenstein,

As an active researcher on biological effects of electromagnetic fields (EMF) for over twenty five years at Columbia University, as well as one of the organizers of the 2007 online Bioinitiative Report on the subject, I am writing in support of a limit on the construction of cell towers in the vicinity of schools.

There is now sufficient scientific data about the biological effects of EMF, and in particular about radiofrequency (RF) radiation, to argue for adoption of precautionary measures. We can state unequivocally that EMF can cause single and double strand DNA breakage at exposure levels that are considered safe under the FCC guidelines in the USA. As I shall illustrate below, there are also epidemiology studies that show an increased risk of cancers associated with exposure to RF. Since we know that an accumulation of changes or mutations in DNA is associated with cancer, there is good reason to believe that the elevated rates of cancers among persons living near RF towers are probably linked to DNA damage caused by EMF. Because of the nature of EMF exposure and the length of time it takes for most cancers to develop, one cannot expect ‘conclusive proof’ such as the link between helicobacter pylori and gastric ulcer. (That link was recently demonstrated by the Australian doctor who proved a link conclusively by swallowing the bacteria and getting the disease.) However, there is enough evidence of a plausible mechanism to link EMF exposure to increased risk of cancer, and therefore of a need to limit exposure, especially of children.

EMF have been shown to cause other potentially harmful biological effects, such as leakage of the blood brain barrier that can lead to damage of neurons in the brain, increased micronuclei (DNA fragments) in human blood lymphocytes, all at EMF exposures well below the limits in the current FCC guidelines. Probably the most convincing evidence of potential harm comes

from living cells themselves when they start to manufacture stress proteins upon exposure to EMF. The stress response occurs with a number of potentially harmful environmental factors, such as elevated temperature, changes in pH, toxic metals, etc. This means that ***when stress protein synthesis is stimulated by radiofrequency or power frequency EMF, the body is telling us in its own language that RF exposure is potentially harmful.***



There have been several attempts to measure the health risks associated with exposure to RF, and I can best summarize the findings with a graph from the study by Dr. Neil Cherry of all childhood cancers around the Sutro Tower in San Francisco between the years 1937 and 1988. Similar studies with similar results were done around broadcasting antennas in Sydney, Australia and Rome, Italy, and there are now studies of effects of cellphones on brain cancer. The Sutro tower contains antennas for broadcasting FM (54.7 kW), TV (616 kW) and UHF (18.3 MW) signals over a fairly wide area, and while the fields are not uniform, and also vary during the day, the fields were measured and average values estimated, so that one could associate the cancer risk with the degree of EMF exposure.

The data in the figure are the risk ratios (RR) for a total of 123 cases of childhood cancer from a population of 50,686 children, and include a 51 cases of leukaemia, 35 cases of brain cancer and 37 cases of lymphatic cancer. It is clear from the results that the risk ratio for all childhood cancers is elevated in the area studied, and while the risk falls off with radial distance from the antennas, as expected, it is still above a risk ratio of 5 even at a distance of 3km where the field was 1μW/cm^2. This figure is what we can expect from prolonged RF exposure. In the Bioinitiative Report, we recommended 0.1μW/cm^2 as a desirable precautionary level based on this and related studies, including recent studies of brain cancer and cellphone exposure.

As I mentioned above, many potentially harmful effects, such as the stress response and DNA strand breaks, occur at nonthermal levels (field strengths that do not cause a temperature increase) and are therefore considered safe. It is obvious that the safety standards must be revised downward to take into account the nonthermal as well as thermal biological responses that occur at much lower intensities. Since we cannot rely on the current standards, it is best to act according to the precautionary principle, the approach advocated by the European Union and the scientists involved in the Bioinitiative report. In light of the current evidence, the precautionary approach appears to be the most reasonable for those who must protect the health and welfare of the public and especially its most vulnerable members, children of school-age.

Sincerely yours,

Martin Blank, Ph.D.
Associate Professor of Physiology and Cellular Biophysics.

Appendix 4

Comments on use of Wi-Fi & smart/mobile phones in schools

A Need for Caution?

The recent classification of RF/microwave radiation as a Class 2B carcinogen by the International Agency for Research on Cancer (IARC) (WHO/IARC 2011), the Council of Europe's recommendation that electromagnetic emissions should be "*as low as reasonably achievable*" (PACE 2011) and calls - such as that of the Seletun Resolution (Fragopoulou et al. 2010) - to reduce electromagnetic fields (EMF) exposures, indicate it may be wise to reassess current UK policies as related to the use of Wi-Fi and smart/mobile phone use in schools, particularly as low field alternatives are available. UK unions state "*Caution should be used to prevent exposure to substances in Group 2B*," and that "*the aim should be to remove all exposure to any known or suspected carcinogen in the workplace*" (TUC 2008).

Influence of field regimes on clumping of red blood cells

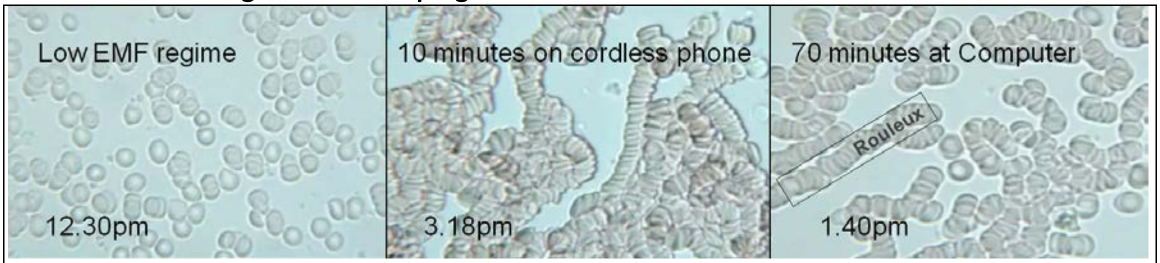
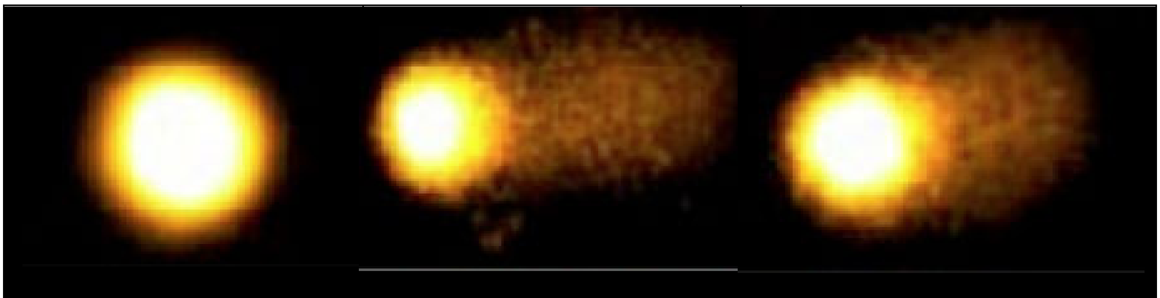


Image source: Havas (2010).

"*Wireless communication is now being implemented in our daily life in a very fast way. At the same time, it is becoming more and more obvious that the exposure to electromagnetic fields not only may induce acute thermal effects to living organisms, but also non-thermal effects, the latter often after longer exposures. This has been demonstrated in a very large number of studies and includes cellular DNA-damage, disruptions and alterations of cellular functions like increases in intracellular stimulatory pathways and calcium handling, disruption of tissue structures like the blood-brain barrier, impact on vessel and immune functions, and loss of fertility*," Johansson (2011).

Comet Assay - a typical picture after RF-EMF-exposition of HL60 leukaemia cells



Sham Image source: Adlkofer (2004).	Gamma-irradiation, 0.5 Gy (1,600 chest x-rays)	24 h mobile phone, RF-EMF, 180 MHz at SAR = 1.3 W/k ICNIRP/WHO = 2 W/kg

The photos above show the effects of different types of radiation on gene expression of human HL60 cells. The damage from radiation from the mobile phone [at levels below current ICNIRP/WHO standards [and which the UK's Health Protection Agency (HPA 2012) currently adheres to], are similar to those resulting from the high dosage of gamma radiation (Adlkofer 2004).

It is noted by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) that *"… children, the elderly, and some chronically ill people might have a lower tolerance for one or more forms of [non-ionising radiation] exposure than the rest of the population."* (ICNIRP 2002).

Some Within Industry Also Suggest Caution

When wishing to consider whether the use of Wi-Fi and smart/mobile phones in schools (and exposing school occupants to such radiation) is appropriate, it is perhaps worth also considering what is being said within some sectors of the telecommunications industry:

"*I want to be very clear. Industry has not said once - once - that … [RF / microwave radiation is] safe. The federal government and various interagency working groups have said it is safe*." K. Dane Snowden, Vice President, External & State Affairs, CTIA-The Wireless Association®* (Safeschool 2010).

* CTIA - The Wireless Association®, is the International Association for the Wireless Telecommunications Industry. It is "Dedicated to Expanding the Wireless Frontier".

"*The influence of electrosmog* [created by inappropriately design technology – present author's comment] *on the human body is a known problem. ... The risk of damage to health through electrosmog has also become better understood as a result of more recent and improved studies. When for example, human blood cells are irradiated with electromagnetic fields, clear damage to hereditary material has been demonstrated and there have been indications of an increased cancer risk*. ..." Swisscom AG - major Swiss telecommunications provider (Swisscom AG 2003).

Warnings - Mobile phone manuals too now carry warnings: As an example, one states that studies "*have suggested that low levels of RF could accelerate the development of cancer in laboratory animals. In one study, mice genetically altered to be predisposed to developing one type of cancer developed more than* ***twice as many cancers*** [emphasis by current author] *when they were exposed to RF energy compared to controls*," (Motorola 2011).

Another mobile phone manual gives the following guidance: "***When using iPhone near your body for voice calls or wireless data transmission over a cellular network, keep iPhone at least 15 mm (5/8 inch away from the body)***, [emphasis by current author] *and only use carrying cases, belt clips, or holders that do not have metal parts and that maintain at least 15 mm (5/8 inch) separation*." (Apple 2010). The text for that warning was originally in grey in 6 font, making it particularly difficult for many people to read:

"When using iPhone near your body for voice calls or wireless data transmission over a cellular network, keep iPhone at least 15 mm (5/8 inch away from the body), and only use carrying cases, belt clips, or holders that do not have metal parts and that maintain at least 15 mm (5/8 inch) separation."

Studies on Learning Ability & RF/Microwave Exposure

The hippocampus

The brain's hippocampus plays a vital role in consolidating information from short-term memory to the long-term memory and in matters related to spatial navigation in both children and adults. Some RF/microwave regimes have been indicated as damaging it and also compromising its development. Animal tests by Salford et al. (2003) reported exposure to 915 MHz RF/microwave regimes from mobile phones for 2 hours produced highly significant ($p < 0.002$) evidence of neuronal damage in the hippocampus and other parts of the brain.

Memory function

Nittby et al. (2008) also investigated the possible effects of exposure to 900 MHz radiation on animals' cognitive functioning; 32 out of 56 rats (the rest being either sham exposed or controls) were exposed for 2 hours every week for 55 weeks to RF/microwave mobile phone radiation. After this protracted exposure, they were compared to sham exposed controls. The RF/microwave exposed animals exhibited impaired memory for objects and temporal order of presentation compared to the sham exposed controls ($p = 0.02$). Their results indicated significantly reduced memory functions occurred after 900 MHz RF/microwave exposures ($p = 0.02$).

Research by Fragopoulou et al. (2009) demonstrated that exposing test-animals for approximately 2 hours per day to 900 MHz RF/microwave radiation from a mobile for four days caused cognitive deficits in spatial learning and memory. In that study, the exposed animals were shown to be less proficient in transferring learned information to the following day, and exhibited deficits in consolidation and/or retrieval of learned information.

Narayanan et al. (2009), undertaking tests on 10-12 week old male rats, found exposing them to the 900/1800 MHz RF/microwave radiation of 50 missed calls a day from a mobile phone daily for 4 weeks induced behavioural changes, though the exact cause of these was undetermined. The animals exposed to RF/microwave radiation took longer to undertake tasks, had poorer spatial navigation and exhibited poorer memory function than those unexposed.

2.4 GHz exposures

Research undertaken by Wang & Lai & (2000) indicated that exposure to some 2.45 GHz RF/microwave regimes may affect memory. In that work, the long-term memory and navigational skills of rats appeared negatively influenced by one hour of exposure to 2.45 GHz radiation (pulse width 2ms, 500 pulses/s, average power density of 2,000 $\mu W/cm^2$) as compared to the unexposed control group. Whilst some studies by others failed to replicate this work (MMF 2005), the need for caution with regard to introducing exposures RF/microwave regimes is indicated.

A later study by Li et al. (2008), found exposing rats to a 2.45 GHz pulsed RF/microwave field at an average power density of 1,000 µW/cm^2 for 3 hours daily for up to 30 days resulted in significant deficits in spatial learning and memory performance in the exposed animals.

As a precautionary measure to improve health, wellbeing and learning ability in schools, it may prove prudent to introduce low field regimes wherever possible.

As noted by the U.S. President's Cancer Panel in its 2008-2009 report, "... *just as there are many opportunities for harmful environmental exposures, ample opportunities also exist to intervene in, ameliorate, and prevent environmental health hazards. Governments, industry, the academic and medical communities, and individuals all have untapped power to protect the health of current and future generations ... and reduce the national burden of cancer.*" (US DHSS 2010).

One of these international initiatives is the creation of Health Promoting Schools. This is an initiative that the UK can greatly contribute to.

Health Promoting Schools (HPS)

Schools, Wellbeing & Achievement

It is recognised by the UK Secretary of State for Education, the Right Honourable Michael Gove MP, that "*… the five outcomes for Every Child Matters… are: being healthy, staying safe, enjoying and achieving, making a positive contribution and securing economic well-being. As a statement of five things that we'd like for children - … They are unimpeachable …*" (Gove & Bell 2010).

This foresight is also shared by the UK's Directgov, "*Everyone in the education system must do what is sensible to keep pupils safe and healthy. This includes making the school environment as safe as possible*. ..." Directgov (2011). It therefore appears prudent, where possible, for the UK to minimise electromagnetic pollution in kindergartens, schools and colleges, and use wired alternatives to standard RF/microwave emitting technologies and other low cost/no cost mitigative measures where feasible.

The creation of environments that actively encourage wellbeing may also help contribute deliverables to Prime Minister David Cameron's groundbreaking National Well-being Debate initiative with parameters that might be easily assessed.

The presence or absence of environmental pollutants, such as electromagnetic pollution, may significantly impact on the learning and wellbeing of some individuals and reductions often be achieved at low or no cost. "*Healthy students learn better. The core business of a school is maximising learning outcomes. Effective Health Promoting Schools (HPS) make a major contribution to schools achieving their educational and social goals*." IUHPE (2010).

The essential elements required in HPS, as based on the WHO's Ottawa Charter for Health Promotion (WHO 1986), include having 'Healthy school policies' that are clearly defined in documents or accepted best practices which promote health and well-being; and that the school's physical environment (buildings, grounds and equipment) help promote health.

Another of the essential elements required in HPS is that potential environmental contaminants detrimental to health are addressed (IUHPE 2009).

The reduction of such potential stressors as electromagnetic pollution could be brought in through appropriate low cost/no cost 'best practice' legislation to help protect children. As noted by the UK Secretary of State for Education, when talking about child protection, "*It is critically important that we make some big changes early on and then allow change to be driven from within the system rather than from Whitehall*." (Gove & Bell 2010). Might introducing suitable legislation on electromagnetic hygiene initiatives to create Health Promoting Schools that encourage health, well-being and improved performance for current and future generations be one of the initiatives he champions?

The Parliamentary Assembly of the Council of Europe (PACE) recommends that the member states of the Council of Europe take "*all reasonable measures*" to reduce the exposure of children and young people to manmade electromagnetic fields to those that are 'As Low As Reasonably Achievable' (ALARA) and that preference should be given to adopting wired as opposed to wireless connections to reduce potential exposures (PACE 2011). The question is can the UK take the initiative and lead the way on this issue, or will another country?

> *"Systematic assessment of the health impact of a rapidly changing environment – particularly in areas of technology, work, energy production and urbanization - is essential."* WHO (1986).

"Pupil's education, health and wellbeing should be at the centre of any initiatives to introduce new technologies into schools. The technologies need to be adding value and need to be safe." WFIS (2011). It is proposed by the present author that introducing appropriate electromagnetic hygiene measures and legislation for schools could significantly benefit the UK and lead the way to improved scholastic performance, the development of new generations of 'bio-friendly' technology and increased National Well-being.

References

Apple (2010), text from page 6 of the Apple iPhone 4 information guide.

Adlkofer, F. (2004), Mobilfunk und Gesunfeit, http://www.scribd.com/doc/5467529/Adlkofer-Gesundheitsrisiko-elektromagnetische-Felder

Directgov (2012), Children's human rights, http://www.direct.gov.uk/en/Parents/ParentsRights/DG_4003313).

Fragopoulou et al. (2010). Scientific panel on electromagnetic field health risks: consensus points, recommendations, and rationales. Reviews on Environmental Health, 25(4), pp. 307-317.

Directgov (2011), Pupil health and safety, http://www.direct.gov.uk/en/Parents/Schoolslearninganddevelopment/YourChildsWelfareAtSchool/DG_4016097

Fragopoulou A.F. et al. (2009), Whole body exposure with GSM 900 MHz affects spatial memory in mice. Pathophysiology, 17, pp. 179-187.

Gove, M.A. and Bell, D. (2010), Examination of Witnesses (Question Numbers 60-72), House of Commons Committee, 28 July 2010, http://www.publications.parliament.uk/pa/cm201011/cmselect/cmeduc/395-i/395-i05.htm

Havas (2010), Live Blood & Electrosmog – YouTube, http://www.youtube/watch?v=L7E36zGHxRw

HPA (2012), Wireless Local Area Networks (WLANS), Health Protection Agency, http://www.hpa.org.uk/Topics/Radiation/UnderstandingRadiation/UnderstandingRadiationTopics/ElectromagneticFields/WirelessLocalAreaNetworks/

ICNIRP (2002), ICNIRP Statement – General Approach to Protection Against Non-Ionizing Radiation, International Commission on Non-Ionizing Radiation Protection, 10 pp. http://www.icnirp.de/documents/philosophy.pdf

IUHPE (2010), Promoting health in schools: from evidence to action, http://www.iuhpe.org/uploaded/Activities/Scientific_Affairs/CDC/School%20Health/PHiS_EtA_EN_WEB.pdf

IUHPE (2009), Achieving Health Promoting Schools: Guidelines for Promoting Health in Schools. Version 2 of the document formerly known as 'Protocols and Guidelines for Health Promoting Schools'. International Union for Health Promotion and Education, http://www.iuhpe.org/uploaded/Publications/Books_Reports/HPS_GuidelinesII_2009_English.pdf

Johansson (2011). Open letter on the California Council on Science and Technology's report "Health Impacts of Radio Frequency from Smart Meters", http://bemri.org/publications/doc_download/343-the-california-council-on-science-and-technology-response.html

Li, M. et al. (2008), Elevation of plasma corticosterone levels and hippocampal glucocorticoid receptor translocation in rats: a potential mechanism for cognition impairment following chronic low-power-density microwave exposure, Journal of Radiation Research, 49(2), pp. 163-170.

MMF (2005), Four French studies fail to replicate reports of microwave brain effects in rats exposed to pulsed 2450 MHz exposures, http://www.mmfai.org/public/docs/eng/MMF_GSMA_FollowUpStudies_RatMemoryFrance.pdf

Motorola (2011), Motorola Digital Wireless Telephone User's Guide, 184 pp, http://www.motorola.com/mdirect/manuals/120e.pdf

Narayanan S.N. et al. (2009), Spatial memory performance of Wistar rats exposed to mobile phone. Clinics, 64 (3), pp. 231-234.

Nittby, H. et al. (2008), Cognitive impairment in rats after long-term exposure to GSM-900 mobile phone radiation. Bioelectromagnetics, 29(3), pp. 219-232.

PACE (2011), The potential dangers of electromagnetic fields and their effect on the environment, Parliamentary Assembly Assemblée parlementaire, Resolution 1815, Council of Europe / Conseil de L'Europe.

Safeschool (2010), Dane Snowden of the CTIA does not say cell phones are safe. http://www.youtube.com/safeschool#p/u/5/s5yGTZq06zQ

Salford L.G. et al. (2003), Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones. Environmental Health Perspectives 111 (7), pp. 881-883.

Swisscom AG (2003), Reduction of Electrosmog in Wireless Local Networks, International Application published under the Patent Cooperation Treaty Act (PCT), International Publication Number WO 2004/075583 A1, http://www.next-up.org/pdf/Swisscom_Patentanmeldung.pdf

US DHSS (2010), President's Cancer Panel 2008-2009 Annual Report – Reducing Environmental Cancer: What We Can Do Now, US Department of Health and Human Services.

UNICEF (2012), The Convention on the Rights of the Child, http://www.unicef.org/crc/

UNICEF (1989), Convention on the Rights of the Child. Adopted and opened for signature, ratification and accession by General Assembly resolution 44/25 of 20 November 1989, Entry into force 2 September 1990, in accordance with article 49. http://www2.ohchr.org/english/law/crc.htm

Wang, B.M. & Lai, H. (2000), Acute exposure to pulsed 2450-MHz microwaves affects water-maze performance in rats. Bioelectromagnetics, 21, pp. 52-56.

WHO (1986), Ottawa Charter for Health Promotion, First International Conference on Health Promotion Ottawa, 21 November 1986 - WHO/HPR/HEP/95.1, http://www.who.int/hpr/NPH/docs/ottawa_charter_hp.pdf

WHO/IARC (2011), IARC classifies radiofrequency electromagnetic fields as possibly carcinogenic to humans, Press Release No. 208, World Health Organization, 31st May 2011.

WFIS (2011), BECTA, WiFiinschools.org.uk, http://wifiinschools.org.uk/17.html

Author biography: Email: isaac.jamieson@live.co.uk

Dr Isaac Jamieson is an independent scientist, architect and built environment consultant. He is presently a scientific advisor on stakeholder groups in the EU and UK involved in policy decisions for the creation of healthy environments at national and international level.

Main source document for present article: Smart Meters - Smarter Practices: Solving emerging problems, A review

http://www.radiationresearch.org/index.php?option=com_content&view=article&id=173

Appendix 5

Governmental Protection Against Radiation is in Conflict With Science

Professor Dr. Franz Adlkofer, MD.

There is no technology that made its way as quickly and as extensively into people's daily life like wireless communication. In only 30 years, the number of mobile phone users has world-wide increased from zero to about five billion. While the use of mobile phones is the result of people's free choice, their exposure to W-LAN and other wireless applications is mostly compulsory. Especially concerned are children in schools where this technology has been given preference to wired computers. Since our knowledge on possible adverse effects of radiofrequency electromagnetic fields is still rather poor, it is obvious that at present the biggest biophysical experiment of mankind is under way – with an uncertain outcome.

In May 2011, the uncertainty has been strengthened by the International Agency for Research on Cancer (IARC) that classified radiofrequency electromagnetic fields as 'possibly carcinogenic to humans'. This decision was mainly based on the results of epidemiological studies that observed after long-term (>10 years) and intensive use of mobile phones an increased risk for brain tumours exactly at the side of the head at which the mobile phone was used. The results from animal experiments, although of minor significance, supported the decision. Yet, results from basic research that showed changes in structure and functions of genes in isolated human and animal cells as well as in living animals after exposure and that would have given additional weight to the epidemiological observations were not taken into account. Had they been included in the evaluation, the classification would not have been 'possibly carcinogenic' but rather 'probably carcinogenic'.

The biggest dilemma is caused by the fact that the general public is confronted with two different views, one represented by politics and industry and one by the growing number of independent researchers. Ordinary people have either no idea of the probably adverse effects of radiofrequency radiation or have full confidence in the exposure limits that according to their governments reliably protect from any risk to the health. They do not know that the exposure limits are based on pseudo-science thought to create the necessary legal frame for a telecommunication industry that wants to make use of the new technology without being hampered by medical considerations. For this purpose, the exposure limits were based on physical deliberations solely accepting the existence of biological effects through temperature increase. The occurrence of biological effects far below the exposure limits, meanwhile demonstrated in numerous studies, was totally neglected. The human brain contains hundred billions of living cells, which operate and communicate with each other on the basis of electrochemical mechanisms. That these mechanisms can be deranged quite easily by electromagnetic fields has been shown many times by now. However, it is well known that

findings in conflict with industrial policies require decades of research and discussion until they are finally accepted.

For a medical doctor like me, the conclusion from the present state of knowledge must be that a precautionary approach is overdue and must not be delayed anymore.

As the organizer and coordinator of the EU funded REFLEX study carried out between 2000 and 2004 by 12 research groups from seven European countries, I had to realize that radiofrequency radiation far below the exposure limits owes - opposite to our expectations – a genotoxic potential, thus, contradicting the reliability of the current exposure limits. Our results are in line with those reported in many other scientific papers that in the meantime add up to more than 100. Up to now, all these findings are not considered in the radiation protection policy of most countries all over the world. Based on my experience gathered in more than 20 years of research in the area of electromagnetic fields, I came to the conclusion that institutional corruption is responsible (1) for the still miserable state of knowledge on biological effects of electromagnetic fields, and (2) for the blindness of most governments in regard of the growing set of data that cry out for the acceptance of the precautionary principle. The poor state of knowledge is due to selective funding of research by government and industry and the willingness of hired scientists to adjust their findings to the needs of the awarding authorities, while the governmental blindness is the result of lobbyism in the antechambers of political power (http://www.pandora-foundation.eu/downloads/harvard_23-03-2012_en.pdf). To those who are mostly affected by such an irresponsible attitude belong certainly our children. This is due to a higher susceptibility of juvenile tissue to radiofrequency radiation and – probably more important – to their high life expectancy that gives any tumour enough time to grow.

It remains to be seen how long the truth about the effects of radiofrequency radiation on the health of people can be suppressed by denying the facts. History teaches that early warnings are far too often followed by late insights for which a great number of people may have to pay with disease and premature death.

Prenatal & Children - Stem Cells; Microwaves from Mobile Phones Inhibit 53BP1 Focus Formation in Human Stem Cells More Strongly Than in Differentiated Cells: Possible Mechanistic Link to Cancer Risk. Environmental Health Perspectives (Markova, Belyaev et al); 2010

Microwaves from Mobile Phones Inhibit 53BP1 Focus Formation in Human Stem Cells More Strongly Than in Differentiated Cells: Possible Mechanistic Link to Cancer Risk

Eva Markovà,[1,2] Lars O.G. Malmgren,[3] and Igor Y. Belyaev[1,2,4]

[1]Department of Genetics, Microbiology and Toxicology, Stockholm University, Stockholm, Sweden; [2]Laboratory of Molecular Genetics, Cancer Research Institute, Bratislava, Slovak Republic; [3]MAX-lab, Lund University, Lund, Sweden; [4]Laboratory of Radiobiology, General Physics Institute, Russian Academy of Science, Moscow, Russia

Background: It is widely accepted that DNA double-strand breaks (DSBs) and their misrepair in stem cells are critical events in the multistage origination of various leukemias and tumors, including gliomas.

Objectives: We studied whether microwaves from mobile telephones of the Global System for Mobile Communication (GSM) and the Universal Global Telecommunications System (UMTS) induce DSBs or affect DSB repair in stem cells.

Methods: We analyzed tumor suppressor TP53 binding protein 1 (53BP1) foci that are typically formed at the sites of DSB location (referred to as DNA repair foci) by laser confocal microscopy.

Results: Microwaves from mobile phones inhibited formation of 53BP1 foci in human primary fibroblasts and mesenchymal stem cells. These data parallel our previous findings for human lymphocytes. Importantly, the same GSM carrier frequency (915 MHz) and UMTS frequency band (1947.4 MHz) were effective for all cell types. Exposure at 905 MHz did not inhibit 53BP1 foci in differentiated cells, either fibroblasts or lymphocytes, whereas some effects were seen in stem cells at 905 MHz. Contrary to fibroblasts, stem cells did not adapt to chronic exposure during 2 weeks.

Conclusions: The strongest microwave effects were always observed in stem cells. This result may suggest both significant misbalance in DSB repair and severe stress response. Our findings that stem cells are most sensitive to microwave exposure and react to more frequencies than do differentiated cells may be important for cancer risk assessment and indicate that stem cells are the most relevant cellular model for validating safe mobile communication signals.

Key words: 53BP1 foci, DNA double-strand breaks, microwaves, mobile phones, stem cells. *Environ Health Perspect* 118:394–399 (2010). doi:10.1289/ehp.0900781 available via *http://dx.doi.org/* [Online 23 October 2009]

The intensity levels of exposure to microwaves (MWs) from mobile telephones are lower than the International Commission on Non-ionizing Radiation Protection (ICNIRP) standards, which are based on thermal effects of acute MW exposures (ICNIRP 1998). However, effects of prolonged exposure to nonthermal (NT) MWs at intensities comparable with those of mobile phones have also been observed in many studies that indicate a relationship between NT MW exposure and permeability of the brain–blood barrier (Nittby et al. 2008), cerebral blood flow (Huber et al. 2005), stress response (Blank and Goodman 2004), and neuronal damage (Salford et al. 2003). The data obtained by the comet assay (Diem et al. 2005; Lai and Singh 1997) and the micronuclei assay (d'Ambrosio et al. 2002; Trosic et al. 2002; Zotti-Martelli et al. 2005) imply possible genotoxic effects of NT MWs, whereas other studies did not support this genotoxicity (Meltz 2003). Experimental data have indicated that the NT MW effects occur depending on several physical parameters, including carrier frequency, polarization, modulation, and intermittence (Belyaev 2005a). Differences in these physical parameters and biological variables, including genetic background and physiologic state, may explain various outcomes of studies with NT MWs (Belyaev 2005b; Huss et al. 2007).

A recent review of available epidemiologic studies concluded that the use of mobile phones for > 10 years is associated with increased risk of ipsilateral gliomas and acoustic neurinomas (Hardell et al. 2008). For a long time stem cells have been considered an important cellular target for origination of cancer—both tumors and leukemia (Feinberg et al. 2006; Soltysova et al. 2005). Gliomas are believed to originate from stem cells in the brain (Altaner 2008). DNA double-strand breaks (DSBs) and their misrepair are critical molecular events resulting in chromosomal aberrations, which have often been associated with origination of various leukemias and tumors, including gliomas (Fischer and Meese 2007). Only one study on possible MW-induced DSBs in stem cells is available (Nikolova et al. 2005). Surprisingly, the data obtained in that study by the neutral comet assay suggested that prolonged exposure time abolished the DSB formation observed at the shorter exposure time. Furthermore, the neutral comet assay has limited applicability to detect DSBs because similar increases in comet tails may be also caused by nongenotoxic effects that imply changes in chromatin conformation, such as relaxation of DNA loops (Belyaev et al. 1999).

Several proteins involved in DSB repair, such as phosphorylated histone 2A family member X (γ-H2AX) and tumor suppressor TP53 binding protein 1 (53BP1), have been shown to produce discrete foci that colocalize to DSBs, referred to as DNA repair foci (Kao et al. 2003; Sedelnikova et al. 2002). Analysis of DNA repair foci is currently accepted as the most sensitive and specific technique for measuring DSBs in untreated cells, as well as in cells exposed to cytotoxic agents (Bocker and Iliakis 2006; Bonner et al. 2008). By analysis of the DNA repair foci in normal human fibroblasts, we were able to detect DSBs induced by a very low dose of ionizing radiation, 1 cGy, which results in only 0.4 DSB/cell on average (Markovà et al. 2007). We have also used this technique to analyze 53BP1/γ-H2AX foci in human lymphocytes exposed to MWs from Global System for Mobile Communication (GSM)/Universal Global Telecommunications System (UMTS) phones (Belyaev et al. 2005, 2009; Markovà et al. 2005). We have found that MW exposure inhibited formation of endogenous 53BP1/γ-H2AX foci (Belyaev et al. 2005, 2009; Markovà et al. 2005). This inhibition might be caused by a decrease in accessibility of DSBs to proteins because of stress-induced chromatin condensation (Belyaev et al. 2009). Inability to form DNA repair foci has been correlated to radiosensitivity, genomic instability, and other

Address correspondence to I.Y. Belyaev, Department of Genetics, Microbiology and Toxicology, Stockholm University, S-106 91 Stockholm, Sweden. Telephone: 46-8-16-41-08. Fax: 46-8-6129552. E-mail: Igor.Belyaev@gmt.su.se

Supplemental Material is available online (doi:10.1289/ehp.0900781.S1 via http://dx.doi.org/).

We thank C. Altaner for valuable discussions at the initial stages of this study and R. Sarimov for help with statistical analysis.

This study was supported by the Swedish Council for Working Life and Social Research, Swedish Animal Welfare Agency, Swedish Radiation Protection Authority, VEGA Grant Agency (2/0167/08) of the Slovak Republic, and National Scholarship Program of the Slovak Republic.

The authors declare they have no competing financial interests.

Received 10 March 2009; accepted 22 October 2009.

JA 06062

repair defects (Bassing et al. 2002; Celeste et al. 2002; Kuhne et al. 2004; Olive and Banath 2004; Taneja et al. 2004). Inhibition of DSB repair may lead to chromosomal aberrations by either illegitimate recombination events (Bassing and Alt 2004) or reduced functionality of nonhomologous end-joining (Fischer and Meese 2007). Therefore, if similar effects on endogenous DNA repair foci are detected in stem cells, this might provide a direct mechanistic link to the epidemiologic data showing association of MW exposure with increased cancer risk.

Although γ-H2AX foci have been used to analyze endogenous and induced DSBs in most studies, recent data have indicated that γ-H2AX foci may also be produced by chromatin structure alternations and may not contain DSBs (Banath et al. 2004; Han et al. 2006; Suzuki et al. 2006; Yu et al. 2006). Accordingly, some γ-H2AX foci may not associate with DNA damage-response proteins such as 53BP1 (Belyaev et al. 2009; Markovà et al. 2005, 2007; McManus and Hendzel 2005). High expression of endogenous γ-H2AX in pluripotent mouse embryonic stem cells (~ 100 large γ-H2AX foci per cell) was not explained by DSBs, DNA degradation, or apoptosis, but it was attributed to the unusual organization of chromatin in mouse embryonic stem cells (Banath et al. 2009). The number of endogenous 53BP1 foci (< 3 foci/nucleus) appeared normal in mouse embryonic stem cells and is comparable with that found in other cell types (Banath et al. 2009). In contrast to γ-H2AX foci, which may be produced by the DSB-relevant and DSB-unrelated mechanisms, 53BP1 is relocalized to DSBs, along with other DNA damage-response proteins, such as phosphorylated ATM (ataxia telangiectasia mutated), Rad50, and MRE11 (meiotic recombination 11), and there is no indication that DSB-unrelated events would result in the formation of the 53BP1 foci (Medvedeva et al. 2007; Yoshikawa et al. 2009). Therefore, in this study we analyzed only 53BP1 foci as a more relevant marker for DSBs.

The differences in the DSB repair pathways between mouse and human stem cells have been described (Banuelos et al. 2008). In general, the comparisons of stem cells across species suggest that significant differences may be observed, so extrapolation from animal stem cell models to human health risk assessment should be done with care (Brons et al. 2007; Ginis et al. 2004). For the present study, we chose human adipose-tissue derived mesenchymal stem cells (MSCs). This cell type displays multipotency with the ability under the correct conditions to differentiate into lineages that cover a wide range of organs and tissues, such as bone, fat, cartilage, muscle, lung, skin, hepatocytes, and neurons (Bunnell et al. 2008; Porada et al. 2006; Sasaki et al. 2008). Of note, MSCs are at higher risk of malignant transformation than are embryonic stem cells (Soltysova et al. 2005).

In contrast to GSM exposure at the frequency of 915 MHz that consistently inhibited DNA repair foci in lymphocytes from 26 persons in total, GSM exposure at 905 MHz did not inhibit DNA repair focus formation, thereby providing evidence that MW effects depend on carrier frequency (Belyaev et al. 2005, 2009; Markovà et al. 2005). In previous studies we investigated MW effects on lymphocytes. However, it would be of interest to analyze the response of human stem cells, which are usually exposed to the mobile phone MWs along with differentiated human cells such as lymphocytes and fibroblasts. Therefore, in the present study we exposed human stem cells and primary human fibroblasts to GSM/UMTS MWs at the same frequencies as we used previously in experiments with human lymphocytes.

Materials and Methods

Cells. Human diploid VH-10 fibroblasts from the foreskin of a normal boy (a gift from A. Kolman, Department of Molecular Biology and Genome Research, Stockholm University) were maintained at 5% CO_2 and 37°C in a humidified incubator as previously described (Markovà et al. 2007). Human MSCs separated from adipose tissue of two healthy persons (described previously by Kucerova et al. 2007), a gift from V. Altanerova (Cancer Research Institute), were cultivated in minimal essential medium (Alpha Medium, low glucose; Gibco Invitrogen, Carlsbad, CA, USA) supplemented with 10% MSC-stimulating supplement (human; StemCell Technologies, Grenoble, France) and 1% antibiotic/antimycotic mix (Gibco Invitrogen; concentration per milliliter of medium: penicillin, 100 U; streptomycin, 100 µg; Fungizone, 0.25 µg). Suspensions of cells 1×10^5 (MSC) or 2×10^5 (VH-10) in 3 mL of medium were seeded on cover slides in Petri dishes (35 × 10 mm; Sarstedt, Nümbrecht, Germany) and incubated at 37°C in 5% CO_2 humidified atmosphere for 36–40 hr until reaching 80% confluence of cells.

Cell exposure. Cells were exposed to GSM/UMTS MWs essentially as described previously (Belyaev et al. 2009; Sarimov et al. 2004). Briefly, exposures were performed using two specially designed installations, each based on a transverse electromagnetic line cell (TEM-cell) and a test mobile phone. The output of each phone was connected by the coaxial cable to the corresponding TEM-cell. Cells were exposed to either GSM (905 MHz or 915 MHz) or UMTS (1947.4 MHz, middle channel), with identical output power (0.25 W), at least three times for each exposure condition. All exposures were performed at 37°C in a 5% CO_2 incubator using Petri dishes containing 3 mL medium per dish. The specific absorption rate (SAR) was 37 mW/kg for the 905/915 MHz frequency and 39 mW/kg for the 1947.4 MHz frequency. Taking into account all possible uncertainties, the SAR values at all locations within exposed samples were always well below thermal effects. Temperature was measured in the MW-exposed samples before, during, and after exposure with a precision of 0.1°C. No changes in temperature were induced in the samples during exposures.

In addition to MWs, mobile phones emit electromagnetic fields of extremely low frequency (ELF) that can also contribute to the exposure effects (Weisbrot et al. 2003). To avoid eventual effects of ELF exposure, the test mobile phones were situated 1 m from the CO_2 incubator containing exposed samples. Accordingly, the ELF emission of our test mobile phones did not increase background ELF field, which did not exceed 200 nT (root mean square), as measured with a three-dimensional microteslameter (Field Dosimeter 3; Combinova, Bromma, Sweden) at the location of MW exposure.

We performed sham exposures in the same TEM-cells with MW power off. The order of MW- and sham-exposures was randomized among sessions. In each experiment, the sham exposures were performed in duplicate in the TEM-cell for GSM exposure and in the TEM-cell for UMTS exposure. No differences were observed between sham-exposed samples (sham – sham exposures). Therefore, we compared the MW effects with reference to combined sham-exposures. Heat treatment (41°C) was used as a positive control for stress response. As a positive control for genotoxic effect, the cells were irradiated with ^{137}Cs γ-rays (3 Gy) using a Gammacell 1000 (Atomic Energy of Canada Limited, Ottawa, Canada) source at 10.6 Gy/min.

Immunostaining and foci analysis. Immediately after exposure, the cells were placed on ice for 1 hr to prevent repair of eventual DSBs. The immunostaining was performed essentially as described previously (Markovà et al. 2005, 2007). The images were recorded from 5–10 fields of vision that were randomly selected from two slides on a Zeiss Axiovert 100M confocal laser scanning microscope using a plan-apochromat 63×/1.4 numerical aperture oil-immersion objective and LSM 510 software (LSM Image Browser 4.2.0.121; Carl Zeiss Microscopy, Jena, Germany). Through-focus maximum projection images were acquired from optical sections 1.00 µm apart and with a section thickness of 2.00 µm in the *z*-axis. Resolutions in the *x*- and *y*-axes were 0.20 µm. Eight optical sections were usually obtained for each field of vision, and the final image was obtained by projection of all sections onto one plane. For each independent exposure

experiment and for each exposure condition (type of cell, type of exposure, exposure duration), we analyzed approximately 300 cells in double-blind fashion.

Statistical analysis. We used Statistica 8.0 (StatSoft Inc., Tulsa, OK, USA) and SPSS Statistics 17.0 (SPSS Inc., Chicago, IL, USA) software for statistical analyses, according to the manufacturer's instructions. Using analysis of variance (ANOVA) for several means, we set the statistical power to 0.80 based on estimates of sample variation and effect size obtained in our pilot experiments. The cell distributions of foci were analyzed using the Kolmogorov-Smirnov test. Most data did not fulfill the Poisson distribution. We analyzed either mean values from independent experiments or all raw data representing foci in each individual cell, using both nonparametric and parametric statistics. Bonferroni adjustment was used in multiple comparisons by ANOVA. In general, all methods provided similar results and conclusions. Results were considered significantly different at $p < 0.05$.

Results

Both in fibroblasts and in MSCs, γ-irradiation (3 Gy) led to significant increases in 53BP1 foci caused by radiation-induced DSBs. In accordance with previously published data (Markovà et al. 2007), 26 foci/cell were found in fibroblasts 2 hr after irradiation, and a slightly higher level, 32 foci/cell, was detected in MSCs [see Supplemental Material, Figure 1 (doi:10.1289/ehp.0900781.S1 via dx.doi.org)]. Although we saw approximately one endogenous 53BP1 focus/cell in sham-exposed fibroblasts (see Supplemental Material, Figure 2), we observed a distinct MW-induced reduction in the level of these foci in response to 915 MHz (Figure 1). UMTS MWs also consistently reduced formation of endogenous 53BP1 foci in fibroblasts (Figure 1). Of note, the MW-induced reduction in 53BP1 foci was the same regardless of the duration of exposure within 1–3 hr, showing that saturation in the effects occurred after a 1-hr exposure (Figure 1). Analysis with the factorial ANOVA confirmed that the data did not depend on the exposure time. To verify the hypothesis that MW exposure for 1–3 hr affected formation of 53BP1 foci, we compared the effects using the Kruskal-Wallis ANOVA by ranks, the median test, and ANOVA. All tests showed that MWs affected formation of 53BP1 foci at highly significant levels ($p < 0.001$). Multiple comparisons showed significant effects of 915 MHz ($p < 0.003$) and UMTS ($p < 0.01$) at 1–3 hr exposure. On the other hand, exposure at 905 MHz did not affect fibroblasts. We observed a statistically significant difference between effects of 915 MHz and 905 MHz exposure ($p < 0.01$). These data parallel our findings for human lymphocytes (Belyaev et al. 2009) and suggest that both lymphocytes and fibroblasts respond to MWs at the same carrier frequencies, whereas other carrier frequencies do not affect these cells. Heat shock significantly inhibited formation of 53BP1 foci, similar to 915 MHz and UMTS MWs ($p < 0.001$). These data are in accordance with our previous findings for human lymphocytes (Belyaev et al. 2005, 2009; Markovà et al. 2005), suggesting that NT MW exposure at specific carrier frequencies induces stress responses similar to heat shock.

The levels of endogenous 53BP1 foci in MSCs were approximately double those in fibroblasts [Figure 2; see also Supplemental Material, Figure 3 (doi:10.1289/ehp.0900781.S1)]. These data parallel the findings of others with mouse embryonic stem cells (Banath et al. 2009). Interestingly, we detected almost no foci in mitotic spreads of chromosomes of both MSCs and fibroblasts. The level of foci in mitotic cells was statistically significantly lower than in interphase cells (data not shown). These results are in line with previously published data indicating that many endogenous 53BP1 foci may not pass mitosis (Markovà et al. 2007).

Similar to our findings for fibroblasts, we observed a distinct MW-induced reduction in the level of endogenous 53BP1 foci in MSCs exposed to 915 MHz and UMTS MW (Figure 2). However, these inhibitory effects of MW exposures were about 2-fold more pronounced in MSCs than in fibroblasts (Figures 1 and 2). As shown in Figure 2, prolongation of exposure did not result in increased inhibition, providing evidence that effects of MW exposure saturated at 1 hr of exposure. Analysis with factorial ANOVA confirmed that the data did not depend on exposure time. The Kruskal-Wallis ANOVA by ranks, the median test, and ANOVA showed that MWs affected formation of 53BP1 foci at very highly significant levels ($p < 0.0001$). The effects of exposure to 915 MHz and UMTS for 1–3 hr were highly significant ($p < 0.0005$). In contrast to fibroblasts, approximately 5% of MSCs had multiple foci [> 10 foci/cell; see Supplemental Material, Figure 4 (doi:10.1289/ehp.0900781.S1)]. The origin of these foci is unknown, but they were completely inhibited by MW exposure (Figure 3). Heat shock at 41°C also inhibited formation of 53BP1 foci in MSCs (Figure 2), although this inhibition was stronger than in the heat-shocked fibroblasts (Figure 1). Altogether, the data provide evidence that exposure to 915 MHz or UMTS MWs, as well as heat shock, results in stronger stress response in MSCs than in fibroblasts. Although we observed some reduction in formation of foci after exposure of MSCs to GSM MW at 905 MHz (Figures 2 and 3), this effect was not statistically significant. The effects of 905 MHz and 915 MHz were also not statistically different. These findings indicate that MWs may affect MSCs at more carrier frequencies compared with differentiated cells.

We further tested whether MSCs and fibroblasts can adapt to MW effects during chronic exposure by exposing the cells for

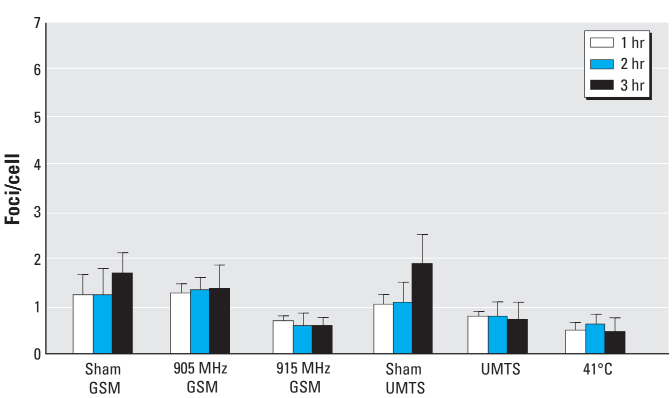


Figure 1. 53BP1 foci in VH-10 fibroblasts after 1-, 2-, or 3-hr exposure to GSM MWs at 905 or 915 MHz, UMTS MWs at 1947.4 MHz, or heat shock at 41°C, as determined by immunostaining and confocal laser microscopy. Values shown are mean ± SD of cells from three to five experiments.

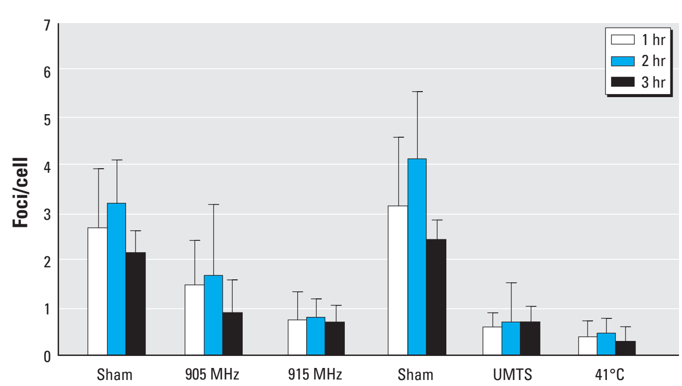


Figure 2. 53BP1 foci in human MSCs after 1-, 2-, or 3-hr exposure to GSM MW at 905 or 915 MHz, UMTS MW at 1947.4 MHz, or heat shock at 41°C. Values shown are mean ± SD from three to five experiments.

JA 06064

2 weeks (5 days/week, 1 hr/day). Interestingly, MSCs with multiple foci almost disappeared during 2 weeks of cultivation of untreated cells. Thus, the levels of endogenous foci did not differ between MSCs and fibroblasts (Figure 4). Fibroblasts almost completely adapted to the chronic MW exposure (Figure 4); however, we saw no such adaptation in MSCs. All statistical tests we used showed that chronic MW exposure affected formation of 53BP1 foci in MSCs ($p < 0.05$, multiple comparisons by Kruskal-Wallis ANOVA by ranks and median tests; $p < 0.001$, ANOVA). Inhibitory effects of MW exposures at the 915 MHz GSM and 1947.4 MHz UMTS were statistically significant during the 2 week exposure of MSCs ($p < 0.05$, Kruskal-Wallis ANOVA; $p < 0.005$, ANOVA). Comparison of arrays containing data from each individual cell confirmed that chronic MW exposure resulted in significant effects in MSCs [see Supplemental Material, Statistics (doi:10.1289/ehp.0900781.S1)]. In addition, these comparisons revealed the effect of 905 MHz GSM exposure and showed that UMTS exposure affected MSCs more strongly than did the GSM exposures.

Discussion

We report here for the first time that exposure of human MSCs and human primary fibroblasts to MWs from GSM/UMTS mobile phones inhibits formation of endogenous 53BP1 foci. Similar although not the same inhibitory effects of MWs from GSM/UMTS mobile phones have previously been found in primary human lymphocytes (Belyaev et al. 2009). We used these cell types for two main reasons. First, the emerging data show that effects of low-intensity MWs are cell-type dependent (Sanchez et al. 2006; Schwarz et al. 2008). In particular, immortalized and primary cells may respond differently to MWs. Therefore, the data obtained with human primary cells would be of utmost relevance for assessing possible health risks of MW exposure from mobile phones. Second, it now appears that most, if not all, adult tissues and organs, including blood, skin, and brain, contain stem cells (Metcalfe and Ferguson 2008). Therefore, stem cells, like blood cells and fibroblasts, are always subjected to exposure from mobile phones.

Our data indicate that fibroblasts are more resistant to MWs than are MSCs (present study) and human peripheral blood lymphocytes (Belyaev et al. 2009). Moreover, we show here that fibroblasts are able to adapt to MWs during chronic exposure. These results are consistent with the suggestion that adaptive cell behavior in response to MW exposure is unlikely to have adverse effects at the skin level (Sanchez et al. 2006). However, we saw no adaptation in MSCs. Thus, although our findings with chronic exposure of fibroblasts may suggest no health risks at the skin level, high sensitivity of stem cells may imply such risks.

No heat was induced in the samples exposed to MW. The SAR values at different locations of the exposed samples were always well below thermal effects. Therefore, the MW effects could not be attributed to heating, although we observed a similar response after both MW exposure and heat shock. This similarity indicates that MW exposure at 915 MHz/1947.4 MHz is a stress factor for fibroblasts and especially for human stem cells, where we saw stronger effects.

Modifications of 53BP1, such as phosphorylation, are needed for repair of DSBs (Ward et al. 2006). Thus, our finding on the inhibition of DNA repair foci can be accounted for by inhibition of phosphorylation of 53BP1 protein. Experimental evidence for such a mechanism has recently been reported (Leszczynski et al. 2002). Alternatively, MW exposure can result in chromatin condensation that prevents DSBs from accessing DNA repair proteins (Belyaev et al. 2005; Markovà et al. 2005; Sarimov et al. 2004). Regardless of the molecular mechanism, inhibition of DSB repair in stem cells may result in chromosomal aberrations by either illegitimate recombination events (Bassing and Alt 2004) or reduced functionality of nonhomologous end-joining (Fischer and Meese 2007).

We have found that the constitutive level of 53BP1 foci in human MSCs is significantly higher than in differentiated primary human cells such as fibroblasts (present study) and lymphocytes (Belyaev et al. 2009). Importantly, we did not observe adaptation to NT GSM/UMTS MW chronic exposure in stem cells. Altogether, our findings show that human stem cells are more sensitive than differentiated primary cells to MW exposure from mobile phones. Thus, inhibition of 53BP1 foci in stem cells may account for higher risks in these cells than in differentiated cells with lower constitutive 53BP1 levels.

In the present study we found that the inhibitory effect of MWs on the 53BP1 foci leveled off at 1 hr of exposure, and we observed no further increase in effects both in MSCs and fibroblasts after prolonging exposure to 3 hr. These data are in agreement with previous results that MW effects were the same at 1 hr and 2 hr exposures in human peripheral blood lymphocytes (Belyaev et al. 2005; Markovà et al. 2005). Preliminary data indicate that saturation in the MW effect is observed at an even shorter exposure time (30 min), whereas almost linear dependence on exposure time is present within shorter exposure times (Belyaev IY, Markovà E, unpublished data).

Both the 1947.4 MHz UMTS frequency band and the 915 MHz GSM signal affected all tested human cell types: stem cells and fibroblasts (present study) and lymphocytes (Belyaev et al. 2009). On the other hand, MW exposure at another GSM frequency (905 MHz) did not result in statistically significant effects in lymphocytes or fibroblasts. Thus, GSM MW exposure may either inhibit or not inhibit DNA repair foci depending on carrier frequency. Neither SAR nor the SAR measurement uncertainty depended on carrier frequency in the range of 905–915 MHz. Therefore, the difference in the effects at 905 and 915 MHz could not be attributed to the differences in the MW absorption. The "frequency" and "intensity" windows have often been reported for NT MW effects (for review, see Belyaev 2005b; Blackman 1992; Grundler 1992). Correspondingly, there may be "effective" and "ineffective" carrier

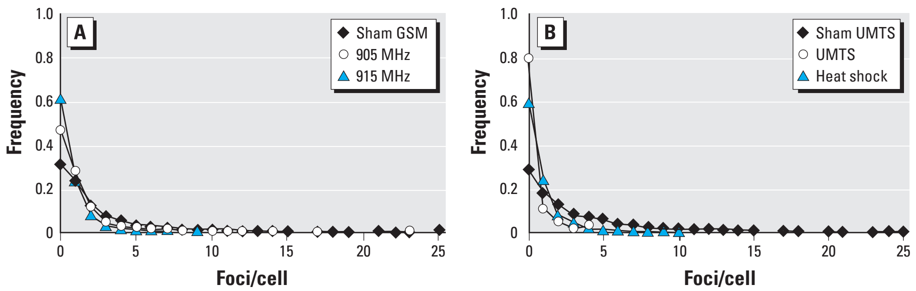


Figure 3. Distribution of 53BP1 foci among MSCs exposed to GSM (*A*) or UMTS (*B*) MWs. Distribution of cells according to number of foci per cell is shown as normalized frequency of cells versus the number of foci per cell. Heat shock (41°C) served as the positive control for MW exposure.

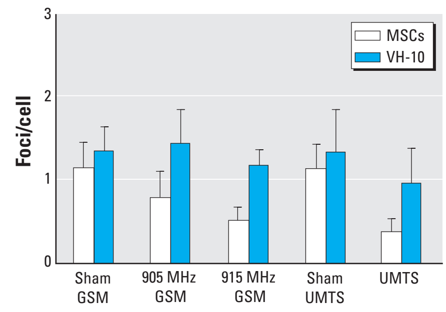


Figure 4. 53BP1 foci in VH-10 fibroblasts and MSCs after chronic exposure during 10 days (5 days/week, 1 hr/day) to GSM MW at 905 MHz or 915 MHz, and UMTS MW at 1947.4 MHz. Values shown are mean ± SD from three experiments.

GSM frequencies that either affect human cells or induce no effect. Several physical mechanisms have been suggested to account for the frequency-dependent effects of NT MW (Belyaev et al. 1996; Binhi 2002; Kaiser 1995; Matronchik and Belyaev 2008). Our previous findings indicated that the intensity windows may not coincide for various carrier frequencies (Belyaev et al. 1996; Shcheglov et al. 1997). Correspondingly, the SAR value of 39 mW/kg used here may be optimal for the effects at 915 MHz but not for those at 905 MHz. Alternatively, but less likely, it is possible that the cells have molecular components that have different electrical properties, thus altering the effective intensity (Joines and Blackman 1980). In either case, future testing of the cell response as a function of exposure intensities at 905 and 915 MHz should help to resolve this issue. Regardless of physical mechanism, our findings suggest that specific carrier frequencies and bands that do not induce adverse effects can be validated in laboratory studies with primary human cells as the prerequisite for the development of safe wireless technologies.

Although we saw no statistically significant effects in stem cells exposed to 905 MHz, by comparing mean values, we observed a trend to inhibition of the DNA repair foci in these cells both under acute and chronic exposures (Figures 2–4). Moreover, the MW effects at 905 and 915 MHz were not statistically significantly different in stem cells, and analysis of the individual cell arrays revealed effects of exposure to 905 MHz. These findings indicate that stem cells may react to more frequencies than do differentiated primary human cells. Higher biological significance of MW effects in stem cells and apparently wider range of effective frequencies suggest that stem cells are the most relevant cellular model for assessment of health risks from mobile communication.

Endogenous 53BP1 foci are typically considered sensitive markers for endogenous DSBs, resulting in intrinsic genomic instability (Adams and Carpenter 2006; Banath et al. 2009; Sedelnikova et al. 2008). However, 53BP1 foci represent only indirect DSB measurements. There is no direct evidence that 53BP1 plays a role in the repair of endogenous DSBs. If irrelevance of the endogenous 53BP1 foci to DSBs is proven, the MW effects described here should be interpreted solely as a manifestation of stress response. This alternative interpretation is supported by the data that MW exposure inhibits 53BP1 foci similar to heating of cells (Figures 1–3). Stress response has previously been suggested as a criterion for adverse effects of electromagnetic fields (Blank and Goodman 2004). In fact, the currently accepted safety standards assume that MW exposure is harmful only if its effects are similar to those of heating (ICNIRP 1998). Stress may be especially important for stem cells because it is believed to be an important factor in the multistage origination of cancer from human stem cells (Feinberg et al. 2006; Tez 2008). Both interpretations of the data—either disruption of the balance between cellular repair systems and DNA damage or stress response—are not mutually exclusive, and both may provide a mechanistic link to the epidemiologic data showing association of prolonged MW exposure with brain cancer risk (Hardell et al. 2008). It should also be mentioned that stress can reduce neurogenesis (Sohur et al. 2006).

The best indications of the role of stem cells in cancer arise from hematologic disorders such as leukemia. In several epidemiologic studies, ELF exposure has been associated with increased childhood leukemia (Kabuto et al. 2006). On the other hand, no association of ELF exposure with leukemia has been found in adults. This discrepancy has not yet been clarified at the mechanistic level, although ELF has been classified as a possible carcinogen based on these studies (International Agency for Research on Cancer 2002). In a recent study Yang et al. (2008) suggested a possible association between electric transformers and power lines and the *XRCC1* Ex9+16A allele in patients with childhood acute leukemia. ELF exposure has often been reported to result in biological effects similar to those caused by exposures to NT MWs (Adey 1981; Blackman 1992), and ELF and MW exposures similarly inhibited formation of DNA repair foci in human lymphocytes (Belyaev et al. 2005). Stem cells are more active in children than in adults (Williams et al. 2006). This increased activity of stem cells may clarify the differences between results obtained in ELF–leukemia studies with children and adults and may call for studies on possible cancer risks of MW exposure of children.

Conclusion

We have demonstrated that GSM/UMTS MWs from mobile phones inhibit formation of endogenous 53BP1 foci in human primary fibroblasts and MSCs. In contrast to fibroblasts, MSCs did not adapt to MWs during chronic exposure. Together, our results indicate that stem cells are more sensitive to MW exposure than are differentiated human primary cells, lymphocytes, and fibroblasts, whereas fibroblasts are least sensitive. Inhibitory effects of MW exposure on DSB repair in stem cells may result in formation of chromosomal aberrations and therefore origination of cancer. Alternatively, MW exposures may induce a stress response. Both possible interpretations provide a mechanistic link to increased cancer risk. Our finding that MSCs may react to more carrier frequencies than differentiated cells may indicate that stem cells are the most relevant cellular model for validating safe mobile communication signals. Because almost all organs and tissues possess stem cells and because stem cells are more active in children, the possible relationship of chronic MW exposure and various types of tumors and leukemia—especially in children—should be investigated.

References

Adams MM, Carpenter PB. 2006. Tying the loose ends together in DNA double strand break repair with 53BP1. Cell Div 1:19; doi: 10.1186/1747-1028-1-19 [Online 31 August 2006].

Adey WR. 1981. Tissue interactions with nonionizing electromagnetic fields. Physiol Rev 61(2):435–514.

Altaner C. 2008. Glioblastoma and stem cells. Neoplasma 55(5):369–374.

Banath JP, Banuelos CA, Klokov D, MacPhail SM, Lansdorp PM, Olive PL. 2009. Explanation for excessive DNA single-strand breaks and endogenous repair foci in pluripotent mouse embryonic stem cells. Exp Cell Res 315(8):1505–1520.

Banath JP, Macphail SH, Olive PL. 2004. Radiation sensitivity, H2AX phosphorylation, and kinetics of repair of DNA strand breaks in irradiated cervical cancer cell lines. Cancer Res 64(19):7144–7149.

Banuelos CA, Banath JP, MacPhail SH, Zhao J, Eaves CA, O'Connor MD, et al. 2008. Mouse but not human embryonic stem cells are deficient in rejoining of ionizing radiation-induced DNA double-strand breaks. DNA Repair (Amst) 7(9):1471–1483.

Bassing CH, Alt FW. 2004. H2AX may function as an anchor to hold broken chromosomal DNA ends in close proximity. Cell Cycle 3(2):149–153.

Bassing CH, Chua KF, Sekiguchi J, Suh H, Whitlow SR, Fleming JC, et al. 2002. Increased ionizing radiation sensitivity and genomic instability in the absence of histone H2AX. Proc Natl Acad Sci USA 99(12):8173–8178.

Belyaev I. 2005a. Nonthermal biological effects of microwaves: current knowledge, further perspective, and urgent needs. Electromagn Biol Med 24(3):375–403.

Belyaev I. 2005b. Non-thermal biological effects of microwaves. Microwave Rev 11(2):13–29. Available: www.mwr.medianis.net/pdf/Vol11No2-03-IBelyaev.pdf [accessed 3 February 2010].

Belyaev IY, Eriksson S, Nygren J, Torudd J, Harms-Ringdahl M. 1999. Effects of ethidium bromide on DNA loop organisation in human lymphocytes measured by anomalous viscosity time dependence and single cell gel electrophoresis. Biochim Biophys Acta 1428(2–3):348–356.

Belyaev IY, Hillert L, Protopopova M, Tamm C, Malmgren LO, Persson BRR, et al. 2005. 915 MHz microwaves and 50 Hz magnetic field affect chromatin conformation and 53BP1 foci in human lymphocytes from hypersensitive and healthy persons. Bioelectromagnetics 26(3):173–184.

Belyaev IY, Markovà E, Hillert L, Malmgren LO, Persson BR. 2009. Microwaves from UMTS/GSM mobile phones induce long-lasting inhibition of 53BP1/gamma-H2AX DNA repair foci in human lymphocytes. Bioelectromagnetics 30(2):129–141.

Belyaev IY, Shcheglov VS, Alipov YD, Polunin VA. 1996. Resonance effect of millimeter waves in the power range from 10^{-19} to 3×10^{-3} W/cm^2 on *Escherichia coli* cells at different concentrations. Bioelectromagnetics 17(4):312–321.

Binhi VN. 2002. Magnetobiology: Underlying Physical Problems. San Diego:Academic Press.

Blackman CF. 1992. Calcium release from nervous tissue: experimental results and possible mechanisms. In: Interaction Mechanisms of Low-Level Electromagnetic Fields in Living Systems (Norden B, Ramel C, eds). Oxford, UK:Oxford University Press, 107–129.

Blank M, Goodman R. 2004. Comment: a biological guide for electromagnetic safety: the stress response. Bioelectromagnetics 25(8):642–646.

Bocker W, Iliakis G. 2006. Computational methods for analysis of foci: validation for radiation-induced gamma-H2AX foci in human cells. Radiat Res 165(1):113–124.

Bonner WM, Redon CE, Dickey JS, Nakamura AJ, Sedelnikova OA, Solier S, et al. 2008. γH2AX and cancer. Nat Rev 8(12):957–967.

JA 06066

Brons IG, Smithers LE, Trotter MW, Rugg-Gunn P, Sun B, Chuva de Sousa Lopes SM, et al. 2007. Derivation of pluripotent epiblast stem cells from mammalian embryos. Nature 448(7150):191–195.
Bunnell BA, Estes BT, Guilak F, Gimble JM. 2008. Differentiation of adipose stem cells. Methods Mol Biol 456:155–171.
Celeste A, Petersen S, Romanienko PJ, Fernandez-Capetillo O, Chen HT, Sedelnikova OA, et al. 2002. Genomic instability in mice lacking histone H2AX. Science 296(5569):922–927.
d'Ambrosio G, Massa R, Scarfi MR, Zeni O. 2002. Cytogenetic damage in human lymphocytes following GMSK phase modulated microwave exposure. Bioelectromagnetics 23(1):7–13.
Diem E, Schwarz C, Adlkofer F, Jahn O, Rudiger H. 2005. Non-thermal DNA breakage by mobile-phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro. Mutat Res 583(2):178–183.
Feinberg AP, Ohlsson R, Henikoff S. 2006. The epigenetic progenitor origin of human cancer. Nat Rev Genet 7(1):21–33.
Fischer U, Meese E. 2007. Glioblastoma multiforme: the role of DSB repair between genotype and phenotype. Oncogene 26(56):7809–7815.
Ginis I, Luo Y, Miura T, Thies S, Brandenberger R, Gerecht-Nir S, et al. 2004. Differences between human and mouse embryonic stem cells. Dev Biol 269(2):360–380.
Grundler W. 1992. Intensity- and frequency-dependent effects of microwaves on cell growth rates. Bioelectrochem Bioenerg 27:361–365.
Han J, Hendzel MJ, Allalunis-Turner J. 2006. Quantitative analysis reveals asynchronous and more than DSB-associated histone H2AX phosphorylation after exposure to ionizing radiation. Radiat Res 165(3):283–292.
Hardell L, Carlberg M, Soderqvist F, Hansson Mild K. 2008. Meta-analysis of long-term mobile phone use and the association with brain tumours. Int J Oncol 32(5):1097–1103.
Huber R, Treyer V, Schuderer J, Berthold T, Buck A, Kuster N, et al. 2005. Exposure to pulse-modulated radio frequency electromagnetic fields affects regional cerebral blood flow. Eur J Neurosci 21(4):1000–1006.
Huss A, Egger M, Hug K, Huwiler-Muntener K, Roosli M. 2007. Source of funding and results of studies of health effects of mobile phone use: systematic review of experimental studies. Environ Health Perspect 115:1–4.
ICNIRP (International Commission on Non-ionizing Radiation Protection). 1998. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Physics 74:494–522.
International Agency for Research on Cancer. 2002. Non-ionizing Radiation, Part I: Static and Extremely Low Frequency (ELF) Electric and Magnetic Fields. IARC Monogr Eval Carcinog Risk Hum 80:1–429.
Joines WT, Blackman CF. 1980. Power density, field intensity, and carrier frequency determinants of RF-energy-induced calcium-ion efflux from brain tissue. Bioelectromagnetics 1(3):271–275.
Kabuto M, Nitta H, Yamamoto S, Yamaguchi N, Akiba S, Honda Y, et al. 2006. Childhood leukemia and magnetic fields in Japan: a case-control study of childhood leukemia and residential power-frequency magnetic fields in Japan. Int J Cancer 119(3):643–650.
Kaiser F. 1995. Coherent oscillations—their role in the interaction of weak ELM-fields with cellular systems. Neural Netw World 5:751–762.
Kao GD, McKenna WG, Guenther MG, Muschel RJ, Lazar MA, Yen TJ. 2003. Histone deacetylase 4 interacts with 53BP1 to mediate the DNA damage response. J Cell Biol 160(7):1017–1027.
Kucerova L, Altanerova V, Matuskova M, Tyciakova S, Altaner C. 2007. Adipose tissue-derived human mesenchymal stem cells mediated prodrug cancer gene therapy. Cancer Res 67(13):6304–6313.
Kuhne M, Riballo E, Rief N, Rothkamm K, Jeggo PA, Lobrich M. 2004. A double-strand break repair defect in ATM-deficient cells contributes to radiosensitivity. Cancer Res 64(2):500–508.
Lai H, Singh NP. 1997. Melatonin and a spin-trap compound block radiofrequency electromagnetic radiation-induced DNA strand breaks in rat brain cells. Bioelectromagnetics 18(6):446–454.
Leszczynski D, Joenvaara S, Reivinen J, Kuokka R. 2002. Non-thermal activation of the hsp27/p38MAPK stress pathway by mobile phone radiation in human endothelial cells: molecular mechanism for cancer- and blood-brain barrier-related effects. Differentiation 70(2–3):120–129.
Markovà E, Hillert L, Malmgren L, Persson BRR, Belyaev IY. 2005. Microwaves from GSM mobile telephones affect 53BP1 and γ-H2AX foci in human lymphocytes from hypersensitive and healthy persons. Environ Health Perspect 113:1172–1177.
Markovà E, Schultz N, Belyaev IY. 2007. Kinetics and dose-response of residual 53BP1/gamma-H2AX foci: co-localization, relationship with DSB repair and clonogenic survival. Int J Radiat Biol 83(5):319–329.
Matronchik AY, Belyaev IY. 2008. Mechanism for combined action of microwaves and static magnetic field: slow non uniform rotation of charged nucleoid. Electromagn Biol Med 27(4):340–354.
McManus KJ, Hendzel MJ. 2005. ATM-dependent DNA damage-independent mitotic phosphorylation of H2AX in normally growing mammalian cells. Mol Biol Cell 16(10):5013–5025.
Medvedeva NG, Panyutin IV, Panyutin IG, Neumann RD. 2007. Phosphorylation of histone H2AX in radiation-induced micronuclei. Radiat Res 168(4):493–498.
Meltz ML. 2003. Radiofrequency exposure and mammalian cell toxicity, genotoxicity, and transformation. Bioelectromagnetics 24(suppl 6):S196–S213.
Metcalfe AD, Ferguson MW. 2008. Skin stem and progenitor cells: using regeneration as a tissue-engineering strategy. Cell Mol Life Sci 65(1):24–32.
Nikolova T, Czyz J, Rolletschek A, Blyszczuk P, Fuchs J, Jovtchev G, et al. 2005. Electromagnetic fields affect transcript levels of apoptosis-related genes in embryonic stem cell-derived neural progenitor cells. FASEB J 19(12):1686–1688.
Nittby H, Grafstrom G, Eberhardt JL, Malmgren L, Brun A, Persson BR, et al. 2008. Radiofrequency and extremely low-frequency electromagnetic field effects on the blood-brain barrier. Electromagn Biol Med 27(2):103–126.
Olive PL, Banath JP. 2004. Phosphorylation of histone H2AX as a measure of radiosensitivity. Int J Radiat Oncol Biol Phys 58(2):331–335.
Porada CD, Zanjani ED, Almeida-Porad G. 2006. Adult mesenchymal stem cells: a pluripotent population with multiple applications. Curr Stem Cell Res Ther 1(3):365–369.
Salford LG, Brun AE, Eberhardt JL, Malmgren L, Persson BRR. 2003. Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones. Environ Health Perspect 111:881–883.
Sanchez S, Milochau A, Ruffie G, Poulletier de Gannes F, Lagroye I, Haro E, et al. 2006. Human skin cell stress response to GSM-900 mobile phone signals. In vitro study on isolated primary cells and reconstructed epidermis. FEBS J 273(24):5491–5507.
Sarimov R, Malmgren LOG, Markovà E, Persson BRR, Belyaev IY. 2004. Non-thermal GSM microwaves affect chromatin conformation in human lymphocytes similar to heat shock. IEEE Trans Plasma Sci 32(4):1600–1608.
Sasaki M, Abe R, Fujita Y, Ando S, Inokuma D, Shimizu H. 2008. Mesenchymal stem cells are recruited into wounded skin and contribute to wound repair by transdifferentiation into multiple skin cell type. J Immunol 180(4):2581–2587.
Schwarz C, Kratochvil E, Pilger A, Kuster N, Adlkofer F, Rudiger HW. 2008. Radiofrequency electromagnetic fields (UMTS, 1,950 MHz) induce genotoxic effects in vitro in human fibroblasts but not in lymphocytes. Int Arch Occup Environ Health 81(6):755–767.
Sedelnikova OA, Horikawa I, Redon C, Nakamura A, Zimonjic DB, Popescu NC, et al. 2008. Delayed kinetics of DNA double-strand break processing in normal and pathological aging. Aging Cell 7(1):89–100.
Sedelnikova OA, Rogakou EP, Panyutin IG, Bonner WM. 2002. Quantitative detection of (125)IdU-induced DNA double-strand breaks with gamma-H2AX antibody. Radiat Res 158(4):486–492.
Shcheglov VS, Belyaev IY, Ushakov VL, Alipov YD. 1997. Power-dependent rearrangement in the spectrum of resonance effect of millimeter waves on the genome conformational state of *E. coli* cells. Electro- Magnetobiol 16(1):69–82.
Sohur US, Emsley JG, Mitchell BD, Macklis JD. 2006. Adult neurogenesis and cellular brain repair with neural progenitors, precursors and stem cells. Philos Trans R Soc Lond B Biol Sci 361(1473):1477–1497.
Soltysova A, Altanerova V, Altaner C. 2005. Cancer stem cells. Neoplasma 52(6):435–440.
Suzuki M, Suzuki K, Kodama S, Watanabe M. 2006. Phosphorylated histone H2AX foci persist on rejoined mitotic chromosomes in normal human diploid cells exposed to ionizing radiation. Radiat Res 165(3):269–276.
Taneja N, Davis M, Choy JS, Beckett MA, Singh R, Kron SJ, et al. 2004. Histone H2AX phosphorylation as a predictor of radiosensitivity and target for radiotherapy. J Biol Chem 279(3):2273–2280.
Tez M. 2008. Cancer is an adaptation mechanism of the aged stem cell against stress. Rejuvenation Res 11(6):1059–1060.
Trosic I, Busljeta I, Kasuba V, Rozgaj R. 2002. Micronucleus induction after whole-body microwave irradiation of rats. Mutat Res 521(1–2):73–79.
Ward I, Kim JE, Minn K, Chini CC, Mer G, Chen J. 2006. The tandem BRCT domain of 53BP1 is not required for its repair function. J Biol Chem 281(50):38472–38477.
Weisbrot D, Lin H, Ye L, Blank M, Goodman R. 2003. Effects of mobile phone radiation on reproduction and development in *Drosophila melanogaster*. J Cell Biochem 89(1):48–55.
Williams DA, Xu H, Cancelas JA. 2006. Children are not little adults: just ask their hematopoietic stem cells. J Clin Invest 116(10):2593–2596.
Yang Y, Jin X, Yan C, Tian Y, Tang J, Shen X. 2008. Case-only study of interactions between DNA repair genes (hMLH1, APEX1, MGMT, XRCC1 and XPD) and low-frequency electromagnetic fields in childhood acute leukemia. Leuk Lymphoma 49(12):2344–2350.
Yoshikawa T, Kashino G, Ono K, Watanabe M. 2009. Phosphorylated H2AX foci in tumor cells have no correlation with their radiation sensitivities. J Radiat Res (Tokyo) 50(2):151–160.
Yu T, MacPhail SH, Banath JP, Klokov D, Olive PL. 2006. Endogenous expression of phosphorylated histone H2AX in tumors in relation to DNA double-strand breaks and genomic instability. DNA Repair (Amst) 5(8):935–946.
Zotti-Martelli L, Peccatori M, Maggini V, Ballardin M, Barale R. 2005. Individual responsiveness to induction of micronuclei in human lymphocytes after exposure *in vitro* to 1800-MHz microwave radiation. Mutat Res 582(1–2):42–52.

JA 06067

Radiation Sickness - Children; Angela Tsiang Comments, Sep. 26, 2016

ID
109262631324881
Proceedings
GN 14-177
IB 15-256
WT RM-11664
WT 10-112
IB 97-95
ET 13-84

Name of Filer Angela Tsiang

Type of Filing COMMENT

Filing Status DISSEMINATED Viewing Status Unrestricted

Date Received Sep 26, 2016 Date Posted Sep 26, 2016
Address Woodbury, MN 55129
City Woodbury State MN ZIP 55129

Brief Comment
I am in opposition to 5G rollout, because the government has not done any studies on long-term health effects from exposure to 5G spectrum. In May 2016 the NTP showed a statisical increase in rare brain and heart cancers from rats exposed to cell phone radiation below thermal levels, yet the FCC has not done anything to revise its safety guidelines which are thermal based. To roll out 5G without doing studies on health first is NEGLIGENT. My children became sick from 4G LTE cell towers next to their school, and now we have to avoid cell towers. With FCC plan to put MILLIONS of small cells on residential streets, my children will become more ill. Health effects of 5G should be studied, not ignored!

Radiation Sickness - Children; Abigail DeSesa Comments, Mar. 4, 2013

Ever since the 'Smart Meter' was installed directly below my 13 year old son's bedroom on our neighbor's house he has had nonstop headaches. We feel there needs to be more restrictions on this service. Please help our children!

Cell Towers - Research Abstract Compilation; 78 Studies Showing Health Effects from Cell Tower Radio Frequency Radiation; 2016

Table of Contents

78 Studies Showing Health Effects from Cell Tower Radio Frequency Radiation

Cancer

Wolf R, Wolf D. Increased incidence of cancer near a cell-phone transmitter station. Inter J Cancer Prev 1(2):123-128, 2004.
Significant concern has been raised about possible health effects from exposure to radiofrequency (RF) electromagnetic fields, especially after the rapid introduction of mobile telecommunication systems. Parents are especially concerned with the possibility that children might develop cancer after exposure to the RF emissions from mobile telephone base stations erected in or near schools. The few epidemiologic studies that did report on cancer incidence in relation to RF radiation have generally presented negative or inconsistent results, and thus emphasized the need for more studies that should investigate cohorts with high RF exposure for changes in cancer incidence. The aim of this study is to investigate whether there is an increased cancer incidence in populations, living in a small area, and exposed to RF radiation from a cell-phone transmitter station.
This is an epidemiologic assessment, to determine whether the incidence of cancer cases among individuals exposed to a cell-phone transmitter station is different from that expected in Israel, in Netanya, or as compared to people who lived in a nearby area. Participants are people (n=622) living in the area near a cell-phone transmitter station for 3-7 years who were patients of one health clinic (of DW). The exposure began 1 year before the start of the study when the station first came into service. A second cohort of individuals (n=1222) who get their medical services in a clinic located nearby with very closely matched, environment, workplace and occupational characteristics was used for comparison.
In the area of exposure (area) eight cases of different kinds of cancer were diagnosed in a period of only one year. This rate of cancers was compared both with the rate of 31 cases per 10,000 per year in the general population and the 2/1222 rate recorded in the nearby clinic (area B). Relative cancer rates for female were 10.5 for area A. 0.6 for area B and 1 for the whole town of Netanya. <u>Cancer incidence of women in area A was thus significantly higher (p<0.0001) compared with that of area B and the whole city. A comparison of the relative risk revealed that there were 4.15 times more cases in area than in the entire population. The study indicates an association between increased incidence of cancer and living in proximity to a cell-phone transmitter station.</u>

Yakymenko I, Sidorik E, Kyrylenko S, Chekhun V. Long-term exposure to microwave radiation provokes cancer growth: evidences from radars and mobile communication systems.Exp Oncol. 33(2):62-70, 2011.
In this review we discuss alarming epidemiological and experimental data on possible carcinogenic effects of long term exposure to low intensity microwave (MW) radiation. <u>Recently, a number of reports revealed that under certain conditions the irradiation by low intensity MW can substantially induce cancer progression in humans and in animal models</u>. The carcinogenic effect of MW irradiation is typically manifested after long term (up to 10 years and more) exposure. <u>Nevertheless, even a year of operation of a</u>

powerful base transmitting station for mobile communication reportedly resulted in a dramatic increase of cancer incidence among population living nearby. In addition, model studies in rodents unveiled a significant increase in carcinogenesis after 17-24 months of MW exposure both in tumor-prone and intact animals. To that, such metabolic changes, as overproduction of reactive oxygen species, 8-hydroxi-2-deoxyguanosine formation, or ornithine decarboxylase activation under exposure to low intensity MW confirm a stress impact of this factor on living cells. We also address the issue of standards for assessment of biological effects of irradiation. It is now becoming increasingly evident that assessment of biological effects of non-ionizing radiation based on physical (thermal) approach used in recommendations of current regulatory bodies, including the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines, requires urgent reevaluation. We conclude that recent data strongly point to the need for re-elaboration of the current safety limits for non-ionizing radiation using recently obtained knowledge. We also emphasize that the everyday exposure of both occupational and general public to MW radiation should be regulated based on a precautionary principles which imply maximum restriction of excessive exposure.

Michelozzi P, Ancona C, Fusco D, Forastiere F, Perucci CA, Risk of leukemia and residence near a radio transmitter in Italy. Epidemiology 9 (Suppl) 354p, 1998.
We conducted a small area study to investigate a cluster of leukemia near a high power radio-transmitter in a peripheral area of Rome. The leukemia mortality within 3.5 km (5,863 inhabitants) was higher than expected (SMR=2.5, 95% confident interval 1.07-4.83); the excess was due to a significant higher mortality among men (7 cases observed, SMR=3.5). The results of the Stone's test, after adjusting for socio-economic confounding, showed a significant decline in risk with distance from the transmitter only among men (p=0.005), whereas the p-value for both sexes was p=0.07.

Lourencini da Silva R , Albano F, Lopes dos Santos LR , Tavares AD, Felzenszwalb I, The effect of electromagnetic field exposure on the formation of DNA lesions. Redox Rep 5(5):299-301, 2000.
In an attempt to determine whether electromagnetic field (EMF) exposure might lead to DNA damage, we exposed SnCl2-treated pBR322 plasmids to EMF and analysed the resulting conformational changes using agarose gel electrophoresis. An EMF-dependent potentiation of DNA scission (i.e. the appearance of relaxed plasmids) was observed. In confirmation of this, plasmids pre-exposed to EMF also were less capable of transforming Escherichia coli. The results indicate that EMF, in the presence of a transition metal, is capable of causing DNA damage. These observations support the idea that EMF, probably through secondary generation of reactive oxygen species, can be clastogenic and provide a possible explanation for the observed correlation between EMF exposure and the frequency of certain types of cancers in humans.

Li CY, Liu CC, Chang YH, Chou LP, Ko MC. A population-based case-control study of radiofrequency exposure in relation to childhood neoplasm. Sci Total Environ. 435-436:472-478, 2012.

This population-based case-control study in Taiwan considered incident cases aged 15 years or less and admitted in 2003 to 2007 for all neoplasm (ICD-9-CM: 140-239) (n=2606), including 939 leukemia and 394 brain neoplasm cases. Controls were randomly selected, with a case/control ratio of 1:30 and matched on year of birth, from all non-neoplasm children insured in the same year when the index case was admitted. Annual summarized power (ASP, watt-year) was calculated for each of the 71,185 mobile phone base stations (MPBS) in service between 1998 and 2007. Then, the **annual power density (APD, watt-year/km(2))** of each township (n=367) was computed as a ratio of the total ASP of all MPBS in a township to the area of that particular township. Exposure of each study subject to radio frequency (RF) was indicated by the averaged APD within 5 years prior to the neoplasm diagnosis (cases) or July 1st of the year when the index case was admitted (controls) in the township where the subject lived. Unconditional logistic regression model with generalized estimation equation was employed to calculate the covariate-**adjusted odds ratio [AOR]** of childhood neoplasm in relation to RF exposure. A higher than median averaged APD (approximately 168 WYs/km(2)) was significantly associated with an increased AOR for all neoplasms (1.13; 1.01 to 1.28), but not for leukemia (1.23; 0.99 to 1.52) or brain neoplasm (1.14, 0.83 to 1.55). This study noted a significantly increased risk of all neoplasms in children with higher-than-median RF exposure to MPBS. The slightly elevated risk was seen for leukemia and brain neoplasm, but was not statistically significant. These results may occur due to several methodological limitations.

Johnson EH, Chima SC, Muirhead DE, A cerebral primitive neuroectodermal tumor in a squirrel monkey (Saimiri sciureus). J Med Primatol 28(2):91-96, 1999.
An adult squirrel monkey with a history of long-term exposure to microwave radiation was found at necropsy to have a malignant tumor of the right cerebral cortex. Gross examination revealed a mass with expanding borders in the right frontoparietal cortex with compression of the adjacent lateral ventricle. Microscopy revealed a tumor composed of sheets of moderate-sized cells, resembling an oligodendroglioma, with clear cytoplasm and central nuclei interrupted by delicate vasculature. Malignant features were present in the form of marked nuclear pleomorphism, frequent mitotic figures, and focal necrosis. A neuronal cell origin for this tumor was supported by immunohistochemical analysis, which revealed immunopositivity for neurofilament proteins and neuron-specific enolase. Staining for vimentin and glial fibrillary acid protein was negative, except in reactive astrocytes at the tumor margins and adjacent to intra-tumoral blood vessels. Antibody activity against Ki-67 antigen, a marker of rapidly proliferating tumor cells, and p53 oncoprotein was strongly positive, indicative of the aggressive and malignant nature of this tumor. The tumor was diagnosed as a cerebral primitive neuroectodermal tumor.

Neurological Effects

Khurana VG, Hardell L, Everaert J, Bortkiewicz A, Carlberg M, Ahonen M.

Studies that show **Cell Tower** Health Effects

Epidemiological evidence for a health risk from mobile phone base stations.Int J Occup Environ Health. 16(3):263-267, 2010.

Human populations are increasingly exposed to microwave/radiofrequency (RF) emissions from wireless communication technology, including mobile phones and their base stations. By searching PubMed, we identified a total of 10 epidemiological studies that assessed for putative health effects of mobile phone base stations. Seven of these studies explored the association between base station proximity and neurobehavioral effects and three investigated cancer. We found that eight of the 10 studies reported increased prevalence of adverse neurobehavioral symptoms or cancer in populations living at distances < 500 meters from base stations. None of the studies reported exposure above accepted international guidelines, suggesting that current guidelines may be inadequate in protecting the health of human populations. We believe that comprehensive epidemiological studies of long-term mobile phone base station exposure are urgently required to more definitively understand its health impact.

Hocking B, Westerman R. Neurological abnormalities associated with CDMA exposure. Occup Med (Lond) 51(6):410-413, 2001.

Dysaesthesiae of the scalp and neurological abnormality after mobile phone use have been reported previously, but the roles of the phone per se or the radiations in causing these findings have been questioned. We report finding a neurological abnormality in a patient after accidental exposure of the left side of the face to mobile phone radiation [code division multiple access (CDMA)] from a down-powered mobile phone base station antenna. He had headaches, unilateral left blurred vision and pupil constriction, unilateral altered sensation on the forehead, and abnormalities of current perception thresholds on testing the left trigeminal ophthalmic nerve. His nerve function recovered during 6 months follow-up. His exposure was 0.015-0.06 mW/cm(2) over 1-2 h. The implications regarding health effects of radiofrequency radiation are discussed.

Abdel-Rassoul G, El-Fateh OA, Salem MA, Michael A, Farahat F, El-Batanouny M, Salem E. Neurobehavioral effects among inhabitants around mobile phone base stations. Neurotoxicology. 28(2):434-40, 2007.

BACKGROUND: There is a general concern on the possible hazardous health effects of exposure to radiofrequency electromagnetic radiations (RFR) emitted from mobile phone base station antennas on the human nervous system. AIM: To identify the possible neurobehavioral deficits among inhabitants living nearby mobile phone base stations. METHODS: A cross-sectional study was conducted on (85) inhabitants living nearby the first mobile phone station antenna in Menoufiya governorate, Egypt, 37 are living in a building under the station antenna while 48 opposite the station. A control group (80) participants were matched with the exposed for age, sex, occupation and educational level. All participants completed a structured questionnaire containing: personal, educational and medical histories; general and neurological examinations; neurobehavioral test battery (NBTB) [involving tests for visuomotor speed, problem solving, attention and memory]; in addition to Eysenck personality questionnaire (EPQ). RESULTS: The prevalence of neuropsychiatric complaints as headache (23.5%), memory

changes (28.2%), dizziness (18.8%), tremors (9.4%), depressive symptoms (21.7%), and sleep disturbance (23.5%) were significantly higher among exposed inhabitants than controls: (10%), (5%), (5%), (0%), (8.8%) and (10%), respectively (P<0.05). The NBTB indicated that the exposed inhabitants exhibited a significantly lower performance than controls in one of the tests of attention and short-term auditory memory [Paced Auditory Serial Addition Test (PASAT)]. Also, the inhabitants opposite the station exhibited a lower performance in the problem solving test (block design) than those under the station. All inhabitants exhibited a better performance in the two tests of visuomotor speed (Digit symbol and Trailmaking B) and one test of attention (Trailmaking A) than controls. The last available measures of RFR emitted from the first mobile phone base station antennas in Menoufiya governorate were less than the allowable standard level. CONCLUSIONS AND RECOMMENDATIONS: Inhabitants living nearby mobile phone base stations are at risk for developing neuropsychiatric problems and some changes in the performance of neurobehavioral functions either by facilitation or inhibition. So, revision of standard guidelines for public exposure to RER from mobile phone base station antennas and using of NBTB for regular assessment and early detection of biological effects among inhabitants around the stations are recommended.

Akbari A, Jelodar G, Nazifi S. Vitamin C protects rat cerebellum and encephalon from oxidative stress following exposure to radiofrequency wave generated by a BTS antenna model. Toxicol Mech Methods. 24(5):347-352, 2014.
Radio frequency wave (RFW) generated by base transceiver station has been reported to produce deleterious effects on the central nervous system function, possibly through oxidative stress. This study was conducted to evaluate the effect of RFW-induced oxidative stress in the cerebellum and encephalon and the prophylactic effect of vitamin C on theses tissues by measuring the antioxidant enzymes activity, including: glutathione peroxidase, superoxide dismutase, catalase, and malondialdehyde (MDA). Thirty-two adult male Sprague-Dawley rats were randomly divided into four equal groups. The control group; the control-vitamin C group received L-ascorbic acid (200 mg/kg of body weight/day by gavage) for 45 days. The RFW group was exposed to RFW and the RFW+ vitamin C group was exposed to RFW and received vitamin C. At the end of the experiment, all groups were killed and encephalon and cerebellum of all rats were removed and stored at -70 °C for measurement of antioxidant enzymes activity and MDA. The results indicate that exposure to RFW in the test group decreased antioxidant enzymes activity and increased MDA compared with the control groups ($p < 0.05$). The protective role of vitamin C in the treated group improved antioxidant enzymes activity and reduced MDA compared with the test group ($p < 0.05$). It can be concluded that RFW causes oxidative stress in the brain and vitamin C improves the antioxidant enzymes activity and decreases MDA.

Bak M, Dudarewicz A, Zmyślony M, Sliwinska-Kowalska M. Effects of GSM signals during exposure to event related potentials (ERPs). Int J Occup Med Environ Health. 23(2):191-199, 2010.

Objectives: The primary aim of this work was to assess the effect of electromagnetic field (EMF) from the GSM mobile phone system on human brain function. The assessment was based on the assay of event related potentials (ERPs). Material and Methods: The study group consisted of 15 volunteers, including 7 men and 8 women. The test protocol comprised determination of P300 wave in each volunteer during exposure to the EMF. To eliminate possible effects of the applied test procedure on the final result, the test was repeated without EMF exposure. P300 latency, amplitude, and latency of the N1, N2, P2 waves were analysed. Results: The statistical analysis revealed an effect of EMF on P300 amplitude. In the experiment with EMF exposure, lower P300 amplitudes were observed only at the time in which the volunteers were exposed to EMF; when the exposure was discontinued, the values of the amplitude were the same as those observed before EMF application. No such change was observed when the experiment was repeated with sham exposure, which may be considered as an indirect proof that lower P300 amplitude values were due to EMF exposure. No statistically significant changes were noted in the latencies of the N1, N2, P2 waves that precede the P300 wave, nor in the latency of the P300 itself. Conclusions: The results suggest that exposure to GSM EMF exerts some effects on CNS, including effects on long latency ERPs.

Hinrichs H, Heinze HJ.Effects of GSM electromagnetic field on the MEG during an encoding-retrieval task. Neuroreport. 15(7):1191-1194, 2004.
Potential effects of GSM 1800 electromagnetic fields (EMF) on verbal memory encoding were investigated by recording event-related magnetic fields (ERMF) from the brain during subsequent memory retrieval. Twelve normal subjects participated in the study. After encoding words from a study list presented in the first phase they had to discriminate old from new words mixed together in a test list presented during the second phase. All subjects performed two experimental sessions, one with exposure to EMF during the study phase, and one without. Exposure to EMF changed an early (350-400 ms) task-specific component of the ERMF indicating an interference of EMF and item encoding. Behavioural measures were not significantly affected. Adverse health effects cannot be derived from these data.

Effects on Reproductive Organs and Fertility Effects

Magras, IN, Xenos, TD, RF radiation-induced changes in the prenatal development of mice. *Bioelectromagnetics* 18(6):455-461, 1997.
The possible effects of radiofrequency (RF) radiation on prenatal development has been investigated in mice. This study consisted of RF level measurements and in vivo experiments at several places around an "antenna park." At these locations RF power densities between 168 nW/cm2 and 1053 nW/cm2 were measured. Twelve pairs of mice, divided in two groups, were placed in locations of different power densities and were repeatedly mated five times. One hundred eighteen newborns were collected. They were measured, weighed, and examined macro- and microscopically. A progressive decrease in the number of newborns

per dam was observed, which ended in irreversible infertility. The prenatal development of the newborns, however, evaluated by the crown-rump length, the body weight, and the number of the lumbar, sacral, and coccygeal vertebrae, was improved.

Jelodar G, Nazifi S, Akbari A. The prophylactic effect of vitamin C on induced oxidative stress in rat testis following exposure to 900 MHz radio frequency wave generated by a BTS antenna model. Electromagn Biol Med. 2013 Jan 16. [Epub ahead of print]
Radio frequency wave (RFW) generated by base transceiver station (BTS) has been reported to make deleterious effects on reproduction, possibly through oxidative stress. This study was conducted to evaluate the effect of RFW generated by BTS on oxidative stress in testis and the prophylactic effect of vitamin C by measuring the antioxidant enzymes activity, including glutathione peroxidase, superoxide dismutase (SOD) and catalase, and malondialdehyde (MDA). Thirty-two adult male Sprague-Dawley rats were randomly divided into four experimental groups and treated daily for 45 days as follows: sham, sham+vitamin C (l-ascorbic acid 200 mg/kg of body weight/day by gavage), RFW (exposed to 900 MHz RFW) 'sham' and 'RFW' animals were given the vehicle, i.e., distilled water and the RFW+vitamin C group (received vitamin C in addition to exposure to RFW). At the end of the experiment, all the rats were sacrificed and their testes were removed and used for measurement of antioxidant enzymes and MDA activity. The results indicate that exposure to RFW in the test group decreased antioxidant enzymes activity and increased MDA compared with the control groups ($p < 0.05$). In the treated group, vitamin C improved antioxidant enzymes activity and reduced MDA compared with the test group ($p < 0.05$). It can be concluded that RFW causes oxidative stress in testis and vitamin C improves the antioxidant enzymes activity and decreases MDA.

Lukac N, Massanyi P, Roychoudhury S, Capcarova M, Tvrda E, Knazicka Z, Kolesarova A, Danko J. In vitro effects of radiofrequency electromagnetic waves on bovine spermatozoa motility. J Environ Sci Health A Tox Hazard Subst Environ Eng. 46(12):1417-1423, 2011.
In this study the effects of 1800 MHz GSM-like radiofrequency electromagnetic waves (RF-EMW) exposure on bovine semen was monitored. The experimental samples were analyzed in vitro in four time periods (0, 30, 120 and 420 min) and compared with unexposed samples (control). Spermatozoa motility was determined by computer assisted semen analyzer (CASA). Evaluation of the percentage of motile spermatozoa showed significant ($P < 0.001$) decrease in experimental groups after 120 and 420 min of culture when exposed to microwaves, in comparison to control. Similar spermatozoa motility inhibition was detected for the percentage of progressively motile spermatozoa, too. Average path distance decreased significantly ($p < 0.001$) in experimental groups after 30 and 420 min of culture. Path velocity increased in the experimental groups exposed to RF-EMW after 30 minutes of culture, but subsequently decreased after 420 min of culture, in comparison to control. This indicates a possible initial stimulation and subsequent velocity inhibition of bovine spermatozoa under RF-EMW exposure. Changes in spermatozoa motility were also detected for some fine parameters, too. A significant decrease ($P < 0.001$) was noted for amplitude of lateral

head displacement in the experimental group after 420 minutes of culture. Detailed in vitro motility analysis of bovine spermatozoa exposed to microwave radiation suggested that the parameters of path and velocity at the beginning of the culture significantly increase, but after longer culture (420 minutes) a significant decrease occur in the experimental group as compared to control. In general, results of this experiment indicate a negative time-dependent effect of 1800 MHz RF-EMW radiation on bovine spermatozoa motility.

Effects on Wellbeing

Santini R, Santini P, Danze JM, Le Ruz P, Seigne M.Study of the health of people living in the vicinity of mobile phone base stations: I. Influence of distance and sex. Pathol Biol (Paris) 50(6):369-373, 2002. [Article in French]
A survey study using questionnaire was conducted in 530 people (270 men, 260 women) living or not in vicinity of cellular phone base stations, on 18 Non Specific Health Symptoms. Comparisons of complaints frequencies (CHI-SQUARE test with Yates correction) in relation with distance from base station and sex, show significant ($p < 0.05$) increase as compared to people living > 300 m or not exposed to base station, till 300 m for tiredness, 200 m for headache, sleep disturbance, discomfort, etc. 100 m for irritability, depression, loss of memory, dizziness, libido decrease, etc. Women significantly more often than men ($p < 0.05$) complained of headache, nausea, loss of appetite, sleep disturbance, depression, discomfort and visual perturbations. This first study on symptoms experienced by people living in vicinity of base stations shows that, in view of radioprotection, minimal distance of people from cellular phone base stations should not be < 300 m.

Santini R, Santini P, Le Ruz P, Danze JM, Seigne M, Survey study of people living in the vicinity of cellular phone base stations. Electromag Biol Med 22:41-49, 2003.
A survey study was conducted, using a questionnaire, on 530 people (270 men, 260 women) living or not in proximity to cellular phone base stations. Eighteen different symptoms (Non Specific Health Symptoms-NSHS), described as radiofrequency sickness, were studied by means of the chi-square test with Yates correction. The results that were obtained underline that certain complaints are experienced only in the immediate vicinity of base stations (up to 10 m for nausea, loss of appetite, visual disturbances), and other at greater distances from base stations (up to 100 m for irritability, depressive tendencies, lowering of libido, and up to 200 m for headaches, sleep disturbance, feeling of discomfort). In the 200 m to 300 m zone, only the complaint of fatigue is experienced significantly more often when compared with subjects residing at more than 300 m or not exposed (reference group). For seven of the studied symptoms and for the distance up to 300 m, the frequency of reported complaints is significantly higher ($P < 0.05$) for women in comparison to men. Significant differences are also observed in relation to the ages of subjects, and for the location of subjects in relation to the antennas and to other electromagnetic factors.

Navarro EA, Sequra J, Portoles M, Gomez-Perretta de Mateo C. The Microwave Syndrome: A Preliminary Study in Spain. Electromag Biol Med 22:161-169, 2003.
A health survey was carried out in Murcia, Spain, in the vicinity of a Cellular Phone Base Station working in DCS-1800 MHz. This survey contained health items related to "microwave sickness" or "RF syndrome." The microwave power density was measured at the respondents' homes. Statistical analysis showed significant correlation between the declared severity of the symptoms and the measured power density. The separation of respondents into two different exposure groups also showed an increase of the declared severity in the group with the higher exposure.

Lerchl A, Krüger H, Niehaus M, Streckert JR, Bitz AK, Hansen V. Effects of mobile phone electromagnetic fields at nonthermal SAR values on melatonin and body weight of Djungarian hamsters (Phodopus sungorus). J Pineal Res. 44(3):267-272, 2008.
In three experiments, adult male Djungarian hamsters (Phodopus sungorus) were exposed 24 hr/day for 60 days to radio frequency electromagnetic fields (RF-EMF) at 383, 900, and 1800 MHz, modulated according to the TETRA (383 MHz) and GSM standards (900 and 1800 MHz), respectively. A radial waveguide system ensured a well defined and uniform exposure at whole-body averaged specific absorption rates of 80 mW/kg, which is equal to the upper limit of whole-body exposure of the general population in Germany and other countries. For each experiment, using two identical waveguides, hamsters were exposed (n = 120) and sham-exposed (n = 120) in a blind fashion. In all experiments, pineal and serum melatonin levels as well as the weights of testes, brain, kidneys, and liver were not affected. At 383 MHz, exposure resulted in a significant transient increase in body weight up to 4%, while at 900 MHz this body weight increase was more pronounced (up to 6%) and not transient. At 1800 MHz, no effect on body weight was seen. The results corroborate earlier findings which have shown no effects of RF-EMF on melatonin levels in vivo and in vitro. The data are in accordance with the hypothesis that absorbed RF energy may result in metabolic changes which eventually cause body weight increases in exposed animals. The data support the notion that metabolic effects of RF-EMFs need to be investigated in more detail in future studies.

Kato Y, Johansson O. Reported functional impairments of electrohypersensitive Japanese: A questionnaire survey. Pathophysiology.19(2) 95-100, 2012.
An increasing number of people worldwide complain that they have become electromagnetic hypersensitive (EHS). We conducted a questionnaire survey of EHS persons in Japan. The aim was to identify electromagnetic fields (EMF) and plausible EMF sources that caused their symptoms. Postal questionnaires were distributed via a self-help group, and 75 participants (95% women) responded. Reported major complaints were "fatigue/tiredness" (85%), "headache", "concentration, memory, and thinking" difficulty (81%, respectively). Seventy-two per cent used some form of complementary/alternative therapy. The most plausible trigger of EHS onset was a mobile phone base station or personal handy-phone system (37%). Sixty-five percent experienced health problems to be due to the radiation from other passengers' mobile

phones in trains or buses, and 12% reported that they could not use public transportation at all. Fifty-three percent had a job before the onset, but most had lost their work and/or experienced a decrease in income. Moreover, 85.3% had to take measures to protect themselves from EMF, such as moving to low EMF areas, or buying low EMF electric appliances. EHS persons were suffering not only from their symptoms, but also from economical and social problems.

Hutter HP, Moshammer H, Wallner P, Kundi M. Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations. Occup Environ Med. 63(5):307-313, 2006.
BACKGROUND: The erection of mobile telephone base stations in inhabited areas has raised concerns about possible health effects caused by emitted microwaves. METHODS: In a cross-sectional study of randomly selected inhabitants living in urban and rural areas for more than one year near to 10 selected base stations, 365 subjects were investigated. Several cognitive tests were performed, and wellbeing and sleep quality were assessed. Field strength of high-frequency electromagnetic fields (HF-EMF) was measured in the bedrooms of 336 households. RESULTS: Total HF-EMF and exposure related to mobile telecommunication were far below recommended levels (max. 4.1 mW/m2). Distance from antennae was 24-600 m in the rural area and 20-250 m in the urban area. Average power density was slightly higher in the rural area (0.05 mW/m2) than in the urban area (0.02 mW/m2). Despite the influence of confounding variables, including fear of adverse effects from exposure to HF-EMF from the base station, there was a significant relation of some symptoms to measured power density; this was highest for headaches. Perceptual speed increased, while accuracy decreased insignificantly with increasing exposure levels. There was no significant effect on sleep quality. CONCLUSION: Despite very low exposure to HF-EMF, effects on wellbeing and performance cannot be ruled out, as shown by recently obtained experimental results; however, mechanisms of action at these low levels are unknown.

Bortkiewicz A, Zmyslony M, Szyjkowska A, Gadzicka E. [Subjective symptoms reported by people living in the vicinity of cellular phone base stations: a review of the studies] Med Pr. 55(4):345-351, 2004. [Article in Polish]
The problem of health effects of electromagnetic fields (EMF) emitted by cellular phone base stations evokes much interest in view of the fact that people living in their vicinity are fated to continuous exposure to EMF. None of the studies carried out throughout the world have revealed excessive values of standards adopted by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). A questionnaire was used as a study tool. The results of the questionnaire survey reveal that people living in the vicinity of base stations report various complaints mostly of the circulatory system, but also of sleep disturbances, irritability, depression, blurred vision, concentration difficulties, nausea, lack of appetite, headache and vertigo. The performed studies showed the relationship between the incidence of individual symptoms, the level of exposure, and the distance between a residential area and a base station. This association was observed in both groups of persons, those who linked their complaints

with the presence of the base station and those who did not notice such a relation. Further studies, clinical and those based on questionnaires, are needed to explain the background of reported complaints.

Bortkiewicz A, Gadzicka E, Szyjkowska A, Politański P, Mamrot P, Szymczak W, Zmyślony M. Subjective complaints of people living near mobile phone base stations in Poland. Int J Occup Med Environ Health. 25(1):31-40, 2012.
OBJECTIVES: The aim of our study was to assess the health conditions and subjective symptoms of the inhabitants living in the base stations vicinity and to analyse the relationship between the complaints and level of exposure to electromagnetic fields (EMF).MATERIALS AND METHODS: Our study was performed in housing estates located in five regions of Łódź. The electric field measurements were performed in the buildings located closest to the azimuth of the antennas. Respondents were selected by trained interviewers using an uniform procedure. The number of the households to be examined was set at a minimum of 420. The questionnaire contained: demographic data, occupational and environmental exposure to EMF, health condition, subjective complaints. Results were adjusted for confounders (age, gender, EMF at the workplace and EMF emitted by household equipment) using multiple regression model.RESULTS: 181 men and 319 women from 500 households were examined. Electric field above 0.8 V/m was recorded in 12% of flats. There was no significant correlation between electric field strength and the distance of examined flats from the base stations. To make possible comparison with relevant literature, we analysed also the frequency of the reported symptoms vs. the distance. Headache was declared by 57% people, most frequently (36.4%) living 100-150 m away from the base station compared to people living at longer distances (p = 0.013). 24.4% subjects, mostly living at a distance above 150 m, declared impaired memory. Difference was statistically significant in comparison with people living at other distances (p = 0.004).CONCLUSIONS: The explanation why we did not find any correlation between the electric field strength and frequency of subjective symptoms but found a correlation between subjective symptoms and distance from base station needs further studies. Maybe new metrics of exposure assessment should be adopted for this purpose.

Augner C, Florian M, Pauser G, Oberfeld G, Hacker GW. GSM base stations: Short-term effects on well-being. Bioelectromagnetics. 30:73-80, 2009.
The purpose of this study was to examine the effects of short-term GSM (Global System for Mobile Communications) cellular phone base station RF-EMF (radiofrequency electromagnetic fields) exposure on psychological symptoms (good mood, alertness, calmness) as measured by a standardized well-being questionnaire. Fifty-seven participants were selected and randomly assigned to one of three different exposure scenarios. Each of those scenarios subjected participants to five 50-min exposure sessions, with only the first four relevant for the study of psychological symptoms. Three exposure levels were created by shielding devices in a field laboratory, which could be installed or removed during the breaks between sessions such that double-blinded conditions prevailed. The overall median power flux densities were 5.2 microW/m(2) during "low," 153.6 microW/m(2) during "medium," and 2126.8 microW/m(2) during

"high" exposure sessions. For scenario HM and MH, the first and third sessions were "low" exposure. The second session was "high" and the fourth was "medium" in scenario HM; and vice versa for scenario MH. Scenario LL had four successive "low" exposure sessions constituting the reference condition. Participants in scenarios HM and MH (high and medium exposure) were significantly calmer during those sessions than participants in scenario LL (low exposure throughout) (P = 0.042). However, no significant differences between exposure scenarios in the "good mood" or "alertness" factors were obtained. We conclude that short-term exposure to GSM base station signals may have an impact on well-being by reducing psychological arousal.

Augner C, Hacker GW. Are people living next to mobile phone base stations more strained? Relationship of health concerns, self-estimated distance to base station, and psychological parameters. Indian J Occup Environ Med. 13(3):141-145, 2009.
BACKGROUND AND AIMS: Coeval with the expansion of mobile phone technology and the associated obvious presence of mobile phone base stations, some people living close to these masts reported symptoms they attributed to electromagnetic fields (EMF). Public and scientific discussions arose with regard to whether these symptoms were due to EMF or were nocebo effects. The aim of this study was to find out if people who believe that they live close to base stations show psychological or psychobiological differences that would indicate more strain or stress. Furthermore, we wanted to detect the relevant connections linking self-estimated distance between home and the next mobile phone base station (DBS), daily use of mobile phone (MPU), EMF-health concerns, electromagnetic hypersensitivity, and psychological strain parameters. DESIGN, MATERIALS AND METHODS: Fifty-seven participants completed standardized and non-standardized questionnaires that focused on the relevant parameters. In addition, saliva samples were used as an indication to determine the psychobiological strain by concentration of alpha-amylase, cortisol, immunoglobulin A (IgA), and substance P. RESULTS: Self-declared base station neighbors (DBS </= 100 meters) had significantly higher concentrations of alpha-amylase in their saliva, higher rates in symptom checklist subscales (SCL) somatization, obsessive-compulsive, anxiety, phobic anxiety, and global strain index PST (Positive Symptom Total). There were no differences in EMF-related health concern scales. CONCLUSIONS: We conclude that self-declared base station neighbors are more strained than others. EMF-related health concerns cannot explain these findings. Further research should identify if actual EMF exposure or other factors are responsible for these results.

Blettner M, Schlehofer B, Breckenkamp J, Kowall B, Schmiedel S, Reis U, Potthoff P, Schuez J, Berg-Beckhoff G. Mobile phone base stations and adverse health effects: Phase 1: A population-based cross-sectional study in Germany. Occup Environ Med. 66(2):118-123. 2009.
Abstract OBJECTIVE: The aim of this first phase of a cross-sectional study from Germany was to investigate whether proximity of residence to mobile phone base stations as well as risk perception is associated with health complaints. METHODS: We conducted a population-based multi-phase cross-sectional study within the context of a large panel

survey regularly carried out by a private research institute in Germany. In the initial phase, which we will report on in this paper, 30,047 persons from a total of 51,444 who took part in the nationwide survey also answered questions on how mobile phone base stations affect their health. A list of 38 health complaints was used. A multiple linear regression model was used to identify predictors of health complaints including proximity of residence to mobile phone base stations and risk perception. RESULTS: Of the 30,047 participants (response rate 58.6%), 18.7% of participants were concerned about adverse health effects of mobile phone base stations, while an additional 10.3% attributed their personal adverse health effects to the exposure from them. Participants who are concerned about or attribute adverse health effects to mobile phone base stations and those living in the vicinity of a mobile phone base station (500 m) reported slightly more health complaints than others. CONCLUSIONS: A substantial proportion of the German population is concerned about adverse health effects caused by exposure from mobile phone base stations. The observed slightly higher prevalence of health complaints near base stations can however not be fully explained by attributions or concerns.

Effects on Sleep

Mohammed HS, Fahmy HM, Radwah NM, Elsayed AA. Non-thermal continuous and modulated electromagnetic radiation fields effects on sleep EEG of rats. J Adv Res 4(2) 181-187, 2013.

In the present study, the alteration in the sleep EEG in rats due to chronic exposure to low-level non-thermal electromagnetic radiation was investigated. Two types of radiation fields were used; 900 MHz unmodulated wave and 900 MHz modulated at 8 and 16 Hz waves. Animals has exposed to radiation fields for 1 month (1 h/day). EEG power spectral analyses of exposed and control animals during slow wave sleep (SWS) and rapid eye movement sleep (REM sleep) revealed that the REM sleep is more susceptible to modulated radiofrequency radiation fields (RFR) than the SWS. The latency of REM sleep increased due to radiation exposure indicating a change in the ultradian rhythm of normal sleep cycles. The cumulative and irreversible effect of radiation exposure was proposed and the interaction of the extremely low frequency radiation with the similar EEG frequencies was suggested.

Liu H, Chen G, Pan Y, Chen Z, Jin W, Sun C, Chen C, Dong X, Chen K, Xu Z, Zhang S, Yu Y. (2014) Occupational Electromagnetic Field Exposures Associated with Sleep Quality: A Cross-Sectional Study. PLoS ONE 9(10): e110825. doi:10.1371/journal.pone.0110825.

BACKGROUND: Exposure to electromagnetic field (EMF) emitted by mobile phone and other machineries concerns half the world's population and raises the problem of their impact on human health. The present study aims to explore the effects of electromagnetic field exposures on sleep quality and sleep duration among workers from electric power plant. METHODS: A cross-sectional study was conducted in an

electric power plant of Zhejiang Province, China. A total of 854 participants were included in the final analysis. The detailed information of participants was obtained by trained investigators using a structured questionnaire, which including socio-demographic characteristics, lifestyle variables, sleep variables and electromagnetic exposures. Physical examination and venous blood collection were also carried out for every study subject. RESULTS: After grouping daily occupational electromagnetic exposure into three categories, subjects with long daily exposure time had a significantly higher risk of poor sleep quality in comparison to those with short daily exposure time. The adjusted odds ratios were 1.68 (95%CI: 1.18, 2.39) and 1.57 (95%CI: 1.10, 2.24) across tertiles. Additionally, among the subjects with long-term occupational exposure, the longer daily occupational time apparently increased the risk of poor sleep quality (OR (95%CI): 2.12 (1.23~3.66) in the second tertile; 1.83 (1.07~3.15) in the third tertile). There was no significant association of long-term occupational exposure duration, monthly electric fee or years of mobile-phone use with sleep quality or sleep duration. CONCLUSIONS: The findings showed that daily occupational EMF exposure was positively associated with poor sleep quality. It implies EMF exposure may damage human sleep quality rather than sleep duration.

Hung CS, Anderson C, Horne JA, McEvoy P. Mobile phone 'talk-mode' signal delays EEG-determined sleep onset. Neurosci Lett. 421: 82-86, 2007.
Mobile phones signals are pulse-modulated microwaves, and EEG studies suggest that the extremely low-frequency (ELF) pulse modulation has sleep effects. However, 'talk', 'listen' and 'standby' modes differ in the ELF (2, 8, and 217Hz) spectral components and specific absorption rates, but no sleep study has differentiated these modes. We used a GSM900 mobile phone controlled by a base-station simulator and a test SIM card to simulate these three specific modes, transmitted at 12.5% (23dBm) of maximum power. At weekly intervals, 10 healthy young adults, sleep restricted to 6h, were randomly and single-blind exposed to one of: talk, listen, standby and sham (nil signal) modes, for 30min, at 13:30h, whilst lying in a sound-proof, lit bedroom, with a thermally insulated silent phone beside the right ear. Bipolar EEGs were recorded continuously, and subjective ratings of sleepiness obtained every 3min (before, during and after exposure). After exposure the phone and base-station were switched off, the bedroom darkened, and a 90min sleep opportunity followed. We report on sleep onset using: (i) visually scored latency to onset of stage 2 sleep, (ii) EEG power spectral analysis. There was no condition effect for subjective sleepiness. Post-exposure, sleep latency after talk mode was markedly and significantly delayed beyond listen and sham modes. This condition effect over time was also quite evident in 1-4Hz EEG frontal power, which is a frequency range particularly sensitive to sleep onset. It is possible that 2, 8, 217Hz modulation may differentially affect sleep onset.

Effects on Cells

Neshev NN, Kirilova EI, Environmental-health aspects of pulse-modulated microwaves. Rev Environ Health 11(1-2):85-88, 1996.
Our theoretical model describes the potential influence of irradiation with pulse-modulated microwaves on the conformational oscillations of enzymes in living organisms. Certain values of pulse-repetition time, determined by the period of conformational oscillations of the corresponding type of enzyme, can produce the effect at extremely low power levels. Synchronized oscillations in identical enzyme molecules produce in turn large-scale oscillations within living cells. Thus, short periods of exposure to pulse-modulated microwaves could be beneficial to cellular function, whereas maintaining the amplitude of such oscillations at a maximum for long periods may have a stressful effect on biochemical processes. The model discloses the possible environmental-health risks of long-term exposure in ambient fields that are created by radar, navigation, and communication systems.

Kwee S, Raskmark P, Changes in cell proliferation due to environmental non-ionizing radiation 2. Microwave radiation. Bioelectrochem Bioenerg 44(2) 251-255, 1998.

Due to the use of mobile telephones, there is an increased exposure of the environment to weak radiofrequency (RF) electromagnetic fields, emitted by these devices. This study was undertaken to investigate if the microwave radiation from these fields will have a similar effect on cell proliferation as weak electromagnetic (ELF) fields. The field was generated by signal simulation of the Global System for Mobile communications (GSM) of 960 MHz. Cell cultures, growing in microtiter plates, were exposed in a specially constructed chamber, a Transverse Electromagnetic (TEM) cell. The Specific Absorption Rate (SAR) values for each cell well were calculated for this exposure system. Experiments were performed on cell cultures of transformed human epithelial amnion cells (AMA), which were exposed to 960 MHz microwave fields at three different power levels and three different exposure times, respectively. It was found that cell growth in the exposed cells was decreased in comparison to that in the control and sham exposed cells. Cell proliferation during the period following exposure varied not only with the various SAR levels, but also with the length of exposure time. On the other hand, repeated periods of exposure did not seem to change the effects. There was a general linear correlation between power level and growth change. However, the exposure time required to obtain the maximum effect was not the same for the various power levels. It turned out that at low power level, a maximum effect was first reached after a longer exposure time than at higher power level. A similar phenomenon was registered in the studies on ELF electromagnetic fields. Here, it was found that there was a linear correlation between the length of exposure time to obtain maximum effect and field strength.

Effects on Eyes

Lu L, Xu H, Wang X, Guo G.Increased nitric oxide synthase activity is essential for electromagnetic-pulse-induced blood-retinal barrier breakdown in vivo.Brain Res. 1264:104-10, 2009.
PURPOSE: To examine whether electromagnetic pulses (EMPs) affected the permeability of the **blood-retinal barrier (BRB),** gene expression of occludin and activity of nitric oxide synthase (NOS).**METHODS:** Sprague-Dawley (SD) rats were used and randomized into EMP and control groups. Retinas were removed immediately, and 2 h or 24 h after EMP radiation. BRB permeability was analyzed by transmission electron microscopy and Evans Blue staining. Retinal NOS activity and concentrations of nitrite and nitrate were measured. Occludin mRNA and protein levels were detected by RT-PCR and Western blotting.**RESULTS:** Exposure of SD rats to EMP resulted in increased BRB permeability, with the greatest decrease in occludin at 24 h. Moreover, this permeability defect was also correlated with significant increases in the formation of NO and induction of NOS activity in SD rats. Furthermore, we found that treatment with NOS inhibitor N-nitro-L-arginine methyl ester (L-NAME) blocked BRB breakdown and prevented the increase in NO formation and induction of NOS activity, as well as the decrease in occluding expression.**CONCLUSION:** Taken together, these results support the view that NOS-dependent NO production is an important factor that contributes to EMP-induced BRB dysfunction, and suggests that NOS induction may play an important role in BRB breakdown.

Hässig M, Jud F, Naegeli H, Kupper J, Spiess B. Prevalence of nuclear cataract in Swiss veal calves and its possible association with mobile telephone antenna base stations. Schweiz Arch Tierheilkd. 151(10):471-478, 2009.
The purpose of this study was to valuate the prevalence of nuclear cataract in veal calves and to elucidate a possible impact by mobile phone base stations (MPBS). For this experiment a cohort study was conducted. A follow-up of the geographical location of each dam and its calf from conception through the fetal period up to slaughter was performed. The first trimester of gestation (organogenesis) was particularly emphasized. The activities of selected protective antioxidants (superoxide dismutase, catalase, glutathione peroxidase [GPx]) were assessed in aqueous humor of the eye to evaluate the redox status. Of 253 calves, 79 (32 %) had various degrees of nuclear cataract, but only 9 (3.6 %) calves had severe nuclear cataract. Results demonstrate a relation between the location of veals calves with nuclear cataracts in the first trimester of gestation and the strength of antennas. The number of antennas within 100 to 199 meters was associated with oxidative stress and there was an association between oxidative stress and the distance to the nearest MPBS. Oxidative stress was increased in eyes with cataract (OR per kilometer: 0.80, confidence interval 95 % 0.62,0.93). It has not been shown that the antennas actually affected stress. Hosmer-Lemeshow statistics showed an accuracy of 100 % in negative cases with low radiation, and only 11.11 % accuracy in positive cases with high radiation. This reflects, that there are a lot of other

possibilities for nuclear cataract beside MPBS. Further studies on the influence of electromagnetic fields during embryonic development animal or person at risk are indicated.

Hässig M, Jud F, Spiess B. [Increased occurrence of nuclear cataract in the calf after erection of a mobile phone base station]. Schweiz Arch Tierheilkd. 154(2):82-86, 2012.[Article in German]
We examined and monitored a dairy farm in which a large number of calves were born with nuclear cataracts after a mobile phone base station had been erected in the vicinity of the barn. Calves showed a 3.5 times higher risk for heavy cataract if born there compared to Swiss average. All usual causes such as infection or poisoning, common in Switzerland, could be excluded. The real cause of the increased incidence of cataracts remains unknown.

Jelodar G, Akbari A, Nazifi S. The prophylactic Effect of Vitamin C on Oxidative Stress Indexes in Rat Eyes Following Exposure to Radiofrequency Wave Generated by a BTS Antenna Model. Int J Radiat Biol. 89(2):128-131, 2013.
Purpose: This study was conducted to evaluate the effect of radiofrequency wave (RFW)-induced oxidative stress in the eye and the prophylactic effect of vitamin C on this organ by measuring the antioxidant enzymes activity including: glutathione peroxidase (GPx), superoxide dismutase (SOD) and catalase (CAT), and malondialdehyde (MDA). Materials and methods: Thirty-two adult male Sprague-Dawley rats were randomly divided into four experimental groups and treated daily for 45 days as follows: control, vitamin C (L-ascorbic acid 200 mg/kg of body weight/day by gavage), test (exposed to 900 MHz RFW) and the treated group (received vitamin C in addition to exposure to RFW). At the end of the experiment all animals were killed, their eyes were removed and were used for measurement of antioxidant enzymes and MDA activity. Results: The results indicate that exposure to RFW in the test group decreased antioxidant enzymes activity and increased MDA compared with the control groups (P<0.05). In the treated group vitamin C improved antioxidant enzymes activity and reduced MDA compared to the test group (P<0.05). Conclusions: It can be concluded that RFW causes oxidative stress in the eyes and vitamin C improves the antioxidant enzymes activity and decreases MDA.

Oxidative Stress

Achudume A, Onibere B, Aina F, Tchokossa P. Induction of oxidative stress in male rats subchronically exposed to electromagnetic fields at non-thermal intensities. J Electromagnetic Analysis and Applications 2(8), 482-487, 2010.
To investigate the oxidative stress-inducing potential of non-thermal electromagnetic fields in rats. Male Wister rats were exposed to electrical field intensity of 2.3 ± 0.82 µV/m . Exposure was in three forms: continuous waves, or modulated at 900 MHz or modulated GSM-nonDTX. The radio frequency radiation (RFR) was 1800 MHz, specific

absorption radiation (SAR) (0.95-3.9 W/kg) for 40 and/or 60 days continuously. Control animals were located > 300 m from base station, while sham control animals were located in a similar environmental conditions, but in the vicinity of a non-functional base station. The rats were assessed for thiobarbituric and reactive species (TBARS), reduced glutathione (GSH) content, catalase activity, glutathione reductase (GR) and glucose residue after 40 and 60 days of exposure. At 40 days, electromagnetic radiation failed to induce any significant alterations. However, at 60 days of exposure various attributes evaluated decreased. The respective decreases in both nicotinamide adenine dinucleotide phosphate (NADPH) and Ascorbate- linked lipid peroxidation (LPO) with concomitant diminution in enzymatic antioxidative defense systems resulted in decreased glucose residue. The present studies showed some biochemical changes that may be associated with a prolong exposure to electromagnetic fields and its relationship to the activity of antioxidant system in rat Regular assessment and early detection of antioxidative defense system among people working around the base stations are recommended.

Augner C, Hacker GW, Oberfeld G, Florian M, Hitzl W, Hutter J, Pauser G. Effects of Exposure to GSM mobile phone base station signals on salivary cortisol, alpha-amylase, and Immunoglobulin A. Biomed Environ Sci. 23(3):199-207, 2010.
OBJECTIVE: The present study aimed to test whether exposure to radiofrequency electromagnetic fields (RF-EMF) emitted by mobile phone base stations may have effects on salivary alpha-amylase, immunoglobulin A (IgA), and cortisol levels. METHODS: Fifty seven participants were randomly allocated to one of three different experimental scenarios (22 participants to scenario 1, 26 to scenario 2, and 9 to scenario 3). Each participant went through five 50-minute exposure sessions. The main RF-EMF source was a GSM-900-MHz antenna located at the outer wall of the building. In scenarios 1 and 2, the first, third, and fifth sessions were "low" (median power flux density 5.2 muW/m(2)) exposure. The second session was "high" (2126.8 muW/m(2)), and the fourth session was "medium" (153.6 muW/m(2)) in scenario 1, and vice versa in scenario 2. Scenario 3 had four "low" exposure conditions, followed by a "high" exposure condition. Biomedical parameters were collected by saliva samples three times a session. Exposure levels were created by shielding curtains. RESULTS: In scenario 3 from session 4 to session 5 (from "low" to "high" exposure), an increase of cortisol was detected, while in scenarios 1 and 2, a higher concentration of alpha-amylase related to the baseline was identified as compared to that in scenario 3. IgA concentration was not significantly related to the exposure.CONCLUSIONS: RF-EMF in considerably lower field densities than ICNIRP-guidelines may influence certain psychobiological stress markers.

Marzook EA, Abd El Moneim AE, Elhadary AA. Prootective role of seame oil against mobile phone base station-induced oxidative stress. J Rad Res Appl Sci 7(1):1-6, 2014.
The present study was undertaken to shed the light on the environmental threats associated with the wireless revolution and the health hazards associated with exposure to mobile base station (MBS). Besides, studying the possible protective role of sesame oil (SO) as an antioxidant against oxidative stress. Therefore, the present work was

designed to study the effect of chronic exposure to electromagnetic radiations (EMR), produced by a cellular tower for mobile phone and the possible protective role of sesame oil on glutathione reductase (GSH-Rx), superoxide dismutase (SOD), catalase (CAT), total testosterone and lipid profile (total cholesterol (Tch), triglycerides (TG), low density lipoprotein cholesterol (LDL-c) and high density lipoprotein cholesterol (HDL-c) in male albino rats. Rats were arranged into four groups: the control unexposed, the exposed untreated and the exposed treated groups (1.5 and 3 ml oil). Exposed groups were subjected to electromagnetic field at frequency of 900 MHz, for 24 h/day for 8 weeks, at the same time both treated groups were supplied with oral injection of sesame oil three times per week. At the end of the experiment, blood samples were obtained for determination of the above mentioned variables in serum. The results obtained revealed that TG and testosterone were raised significantly over control in all groups and the significant increase in oil groups occurred in dose dependent manner. SOD and CAT activities were reduced significantly in exposed rats than control and increased significantly in sesame oil groups as the dose of oil increased. Total cholesterol only showed remarkable reduction in the group treated with 3 ml sesame oil. Also, in this latter group, significant elevation of GSH-Rx was recorded. Changes in serum HDL-c and LDL-c followed an opposite trend in exposed and sesame oil groups reflecting their affectation by EMR or sesame oil. In conclusion, all results of the current study proved that sesame oil can be used as an edible oil to attenuate the oxidative stress which could be yielded as a result of chronic exposure to EMR.

Effects on Blood

Kismali G, Ozgur E, Guler G, Akcay A, Sel T, Seyhan N. The influence of 1800 MHz GSM-like signals on blood chemistry and oxidative stress in non-pregnant and pregnant rabbits. Int J Radiat Biol. 88(5):414-419, 2012.

PURPOSE: Environmental electromagnetic fields originate from man-made sources, such as mobile phones and base stations, and have led to increasing public concern about their possible adverse health effects. We aimed to investigate the possible effects of radiofrequency radiation (RFR) generated from these devices on oversensitive animals, such as pregnant rabbits. MATERIALS AND METHODS: In the present study, the effects of whole body 1800 MHz Global System for Mobile Communications (GSM)-like RFR exposure for 15 min/day for seven days on blood chemistry and lipid peroxidation levels in both non-pregnant and pregnant New Zealand White rabbits were investigated. Thirteen-month-old rabbits were studied in the following four groups: Non-pregnant control, non-pregnant RFR-exposed, pregnant control and pregnant RFR-exposed. RESULTS: Lipid peroxidation, namely malondialdehyde (MDA) levels, did not change after RFR exposure. However, blood chemistry parameters, such as cholesterol (CHO), total protein (TP), albumin (ALB), uric acid, creatinin and **creatine kinase (CK)** and creatine kinase-myocardial band isoenzyme (CK-MB) changed due to both pregnancy and RFR exposure. CONCLUSION: Our investigations have been shown that no indication for oxidative stress was detected in the blood of pregnant rabbits upon RF exposure at specific conditions employed in the present study. Minor

changes in some blood chemistry parameters were detected but CK-MB and CK increases were found remarkable. Studies on RFR exposure during pregnancy will help establish international standards for the protection of pregnant women from environmental RFR.

Yurekli AI, Ozkan M, Kalkan T, Saybasili H, Tuncel H, Atukeren P, Gumustas K, Seker S. GSM Base Station Electromagnetic Radiation and Oxidative Stress in Rats. Electromagn Biol Med. 2006;25(3):177-188, 2006.
The ever increasing use of cellular phones and the increasing number of associated base stations are becoming a widespread source of nonionizing electromagnetic radiation. Some biological effects are likely to occur even at low-level EM fields. In this study, a gigahertz transverse electromagnetic (GTEM) cell was used as an exposure environment for plane wave conditions of far-field free space EM field propagation at the GSM base transceiver station (BTS) frequency of 945 MHz, and effects on oxidative stress in rats were investigated. When EM fields at a power density of 3.67 W/m2 (specific absorption rate = 11.3 mW/kg), which is well below current exposure limits, were applied, MDA (malondialdehyde) level was found to increase and GSH (reduced glutathione) concentration was found to decrease significantly ($p < 0.0001$). Additionally, there was a less significant ($p = 0.0190$) increase in SOD (superoxide dismutase) activity under EM exposure.

Jin YB, Lee HJ, Seon Lee J, Pack JK, Kim N, Lee YS. One-year, simultaneous combined exposure of CDMA and WCDMA radiofrequency electromagnetic fields to rats.Int J Radiat Biol. 87(4):416-423, 2011.
PURPOSE: We investigated whether one-year, long-term, simultaneous exposure to code division multiple access (CDMA; 849 MHz) and wideband code division multiple access (WCDMA; 1.95 GHz) radiofrequencies (RF) would induce chronic illness in Sprague-Dawley (SD) rats. **MATERIALS AND METHODS:** Two groups of 40 SD rats (50% males and females in sham and exposed groups) were exposed to CDMA and WCDMA RF simultaneously at 2.0 W/kg for 45 min/day (total 4.0 W/kg), 5 days per week for a total of one year. Body and organ weight measurements, urinalysis, haematological and blood biochemical analysis, and histopathological evaluations were performed. **RESULTS:** The mortality patterns in male and female rats exposed to RF were compared with those found in gender-matched sham control animals. No significant alteration in body weight was observed with the simultaneous combined RF exposure. Most RF-exposed rats showed no significant alteration, based on urinalysis, haematology, blood biochemistry, or histopathology. However, some altered parameters of the complete blood count and serum chemistry were seen in RF-exposed rats. The total tumour incidence was not different between sham-exposed and RF-exposed animals. **CONCLUSIONS:** Our results suggest that one-year chronic exposure to CDMA (849 MHz) and WCDMA (1.95 GHz) RF simultaneously at 2.0 W/kg for 45-min RF exposure periods (total, 4 W/kg) did not increase chronic illness in rats, although there were some altered parameters in the complete blood count and serum chemistry.

Death

Dode AC, Leão MM, Tejo Fde A, Gomes AC, Dode DC, Dode MC, Moreira CW, Condessa VA, Albinatti C, Caiaffa WT. Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil.Sci Total Environ. 409(19):3649-3665, 2011.
Pollution caused by the electromagnetic fields (EMFs) of radio frequencies (RF) generated by the telecommunication system is one of the greatest environmental problems of the twentieth century. The purpose of this research was to verify the existence of a spatial correlation between **base station (BS**) clusters and cases of deaths by neoplasia in the Belo Horizonte municipality, Minas Gerais state, Brazil, from 1996 to 2006 and to measure the human exposure levels to EMF where there is a major concentration of cellular telephone transmitter antennas. A descriptive spatial analysis of the BSs and the cases of death by neoplasia identified in the municipality was performed through an ecological-epidemiological approach, using georeferencing. The database employed in the survey was composed of three data banks: 1. death by neoplasia documented by the Health Municipal Department; 2. BSs documented in ANATEL ("Agência Nacional de Telecomunicações": 'Telecommunications National Agency'); and 3. census and demographic city population data obtained from official archives provided by IBGE ("Instituto Brasileiro de Geografia e Estatística": 'Brazilian Institute of Geography and Statistics'). The results show that approximately 856 BSs were installed through December 2006. Most (39.60%) of the BSs were located in the "Centro-Sul" ('Central-Southern') region of the municipality. Between 1996 and 2006, 7191 deaths by neoplasia occurred and within an area of 500 m from the BS, the mortality rate was 34.76 per 10,000 inhabitants. Outside of this area, a decrease in the number of deaths by neoplasia occurred. The greatest accumulated incidence was 5.83 per 1000 in the Central-Southern region and the lowest incidence was 2.05 per 1000 in the Barreiro region. During the environmental monitoring, the largest accumulated electric field measured was 12.4 V/m and the smallest was 0.4 V/m. The largest density power was 40.78 μW/cm(2), and the smallest was 0.04 μW/cm(2).

Adang D, Remacle C, Vorst AV Results of a long-term low-level microwave exposure of rats. IEEE Trans Microwave Theor Tech 57: 2488-2497, 2009.
This paper summarizes the results of experimental research on biological effects induced by electromagnetic exposure to low-level microwaves. We exposed four-month-old Wistar albino rats during 21 months to two different microwave frequencies and exposure modes, 2 h a day, seven days a week. In order to assess possible biological effects of microwaves, we selected among others the following parameters: leucocytes, erythrocytes, monocytes, neutrophils, lymphocytes, hemoglobin, mean corpuscular hemoglobin concentration, and mortality rate. After three and eight months of exposure, we found a statistically significant difference of about 20% between the 970-MHz continuous wave group and sham-exposed group regarding the monocytes in both considered periods. After 14 and 18 months of exposure, we observed a significant

increase in white blood cells and neutrophils of about 15% and 25%, respectively. Lymphocytes fell down after 18 months of exposure with about 15% compared to the sham-exposed group. No other statistically significant differences were found, except for minor changes with little biological significance. The most obvious effect we detected is the increase in mortality rate of the exposed groups with respect to the sham-exposed group after 21 months of exposure at the age of 25 months. This increase even increases when observing rats until the age of 28 months: mortality in exposed groups then reaches almost twice the value observed in the sham-exposed group.

Effects on Hormones

Eskander EF, Estefan SF, Abd-Rabou AA. How does long term exposure to base stations and mobile phones affect human hormone profiles? Clin Biochem. 45(1-2):157-161, 2012
OBJECTIVES: This study is concerned with assessing the role of exposure to radio frequency radiation (RFR) emitted either from mobiles or base stations and its relations with human's hormone profiles. **DESIGN AND METHODS:** All volunteers' samples were collected for hormonal analysis. **RESULTS:** This study showed significant decrease in volunteers' ACTH, cortisol, thyroid hormones, prolactin for young females, and testosterone levels. **CONCLUSION:** The present study revealed that high RFR effects on pituitary-adrenal axis.

Eşmekaya MA, Seyhan N, Omeroğlu S. Pulse modulated 900 MHz radiation induces hypothyroidism and apoptosis in thyroid cells: A light, electron microscopy and immunohistochemical study. Int J Radiat Biol. 86(12):1106-1116, 2010.
Purpose: In the present study we investigated the possible histopathological effects of pulse modulated Radiofrequency (RF) fields on the thyroid gland using light microscopy, electron microscopy and immunohistochemical methods. Materials and methods: Two months old male Wistar rats were exposed to a 900 MHz pulse-modulated RF radiation at a specific absorption rate (SAR) of 1.35 Watt/kg for 20 min/day for three weeks. The RF signals were pulse modulated by rectangular pulses with a repetition frequency of 217 Hz and a duty cycle of 1:8 (pulse width 0.576 ms). To assess thyroid endocrine disruption and estimate the degree of the pathology of the gland, we analysed structural alterations in follicular and colloidal diameters and areas, colloid content of the follicles, and height of the follicular epithelium. Apoptosis was confirmed by Transmission Electron Microscopy and assessing the activites of an initiator (caspase-9) and an effector (caspase-3) caspases that are important markers of cells undergoing apoptosis. Results: Morphological analyses revealed hypothyrophy of the gland in the 900 MHz RF exposure group. The results indicated that thyroid hormone secretion was inhibited by the RF radiation. In addition, we also observed formation of apoptotic bodies and increased caspase-3 and caspase-9 activities in thyroid cells of the rats that were exposed to modulated RF fields. Conclusion: The overall findings indicated that whole body exposure to pulse-modulated RF radiation that is similar to that emitted by

global system for mobile communications (GSM) mobile phones can cause pathological changes in the thyroid gland by altering the gland structure and enhancing caspase-dependent pathways of apoptosis.

Genetic Effects

Gandhi G, Kaur G, Nisar U. A cross-sectional case control study on genetic damage in individuals residing in the vicinity of a mobile phone base station. Electromagn Biol Med. 2014 Jul 9:1-11. [Epub ahead of print]
Mobile phone base stations facilitate good communication, but the continuously emitting radiations from these stations have raised health concerns. Hence in this study, genetic damage using the single cell gel electrophoresis (comet) assay was assessed in peripheral blood leukocytes of individuals residing in the vicinity of a mobile phone base station and comparing it to that in healthy controls. The power density in the area within 300 m from the base station exceeded the permissive limits and was significantly ($p = 0.000$) higher compared to the area from where control samples were collected. The study participants comprised 63 persons with residences near a mobile phone tower, and 28 healthy controls matched for gender, age, alcohol drinking and occupational sub-groups. Genetic damage parameters of DNA migration length, damage frequency (DF) and damage index were significantly ($p = 0.000$) elevated in the sample group compared to respective values in healthy controls. The female residents ($n = 25$) of the sample group had significantly ($p = 0.004$) elevated DF than the male residents ($n = 38$). The linear regression analysis further revealed daily mobile phone usage, location of residence and power density as significant predictors of genetic damage. The genetic damage evident in the participants of this study needs to be addressed against future disease-risk, which in addition to neurodegenerative disorders, may lead to cancer.

Fucic A, Garaj-Vrhovac V, Skara M, Dimitrovic B, X-rays, microwaves and vinyl chloride monomer: their clastogenic and aneugenic activity, using the micronucleus assay on human lymphocytes. Mutat Res 282(4):265-271, 1992.
Chromosome aberration assays, sister-chromatid exchange techniques and micronucleus assays are commonly used methods for biomonitoring genetic material damaged by chemical or physical agents. On the other hand, their aneugenic activity, which can lead to hypoploidy and may also be associated with carcinogenesis, has not been thoroughly investigated. In our study we chose the micronucleus assay with a new mathematical approach to separate clastogenic from aneugenic activity of three well-known mutagens (vinyl chloride monomer, X-rays and microwaves) on the genome of human somatic cells. The comparison of frequencies of size distribution of micronuclei in the lymphocytes of humans exposed to each of these three mutagens showed that X-rays and microwaves were preferentially clastogens while vinyl chloride monomer showed aneugenic activity as well. Microwaves possess some mutagenic characteristics typical of chemical mutagens.

Esmekaya MA, Aytekin E, Ozgur E, Güler G, Ergun MA, Omeroğlu S, Seyhan N. Mutagenic and morphologic impacts of 1.8GHz radiofrequency radiation on human peripheral blood lymphocytes (hPBLs) and possible protective role of pre-treatment with Ginkgo biloba (EGb 761). Sci Total Environ. 410-411:59-64, 2011.
The mutagenic and morphologic effects of 1.8GHz Global System for Mobile Communications (GSM) modulated RF (radiofrequency) radiation alone and in combination with Ginkgo biloba (EGb 761) pre-treatment in human peripheral blood lymphocytes (hPBLs) were investigated in this study using Sister Chromatid Exchange (SCE) and electron microscopy. Cell viability was assessed with 3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide (MTT) reduction assay. The lymphocyte cultures were exposed to GSM modulated RF radiation at 1.8GHz for 6, 8, 24 and 48h with and without EGb 761. We observed morphological changes in pulse-modulated RF radiated lymphocytes. Longer exposure periods led to destruction of organelle and nucleus structures. Chromatin change and the loss of mitochondrial crista occurred in cells exposed to RF for 8h and 24h and were more pronounced in cells exposed for 48h. Cytoplasmic lysis and destruction of membrane integrity of cells and nuclei were also seen in 48h RF exposed cells. There was a significant increase ($p<0.05$) in SCE frequency in RF exposed lymphocytes compared to sham controls. EGb 761 pre-treatment significantly decreased SCE from RF radiation. RF radiation also inhibited cell viability in a time dependent manner. <u>The inhibitory effects of RF radiation on the growth of lymphoctes were marked in longer exposure periods.</u> EGb 761 pre-treatment significantly increased cell viability in RF+EGb 761 treated groups at 8 and 24h when compared to RF exposed groups alone. <u>The results of our study showed that RF radiation affects cell morphology, increases SCE and inhibits cell proliferation.</u> However, EGb 761 has a protective role against RF induced mutagenity. <u>We concluded that RF radiation induces chromosomal damage in hPBLs but this damage may be reduced by EGb 761 pre-treatment.</u>

<u>Kim JY</u>, <u>Hong SY</u>, <u>Lee YM</u>, <u>Yu SA</u>, <u>Koh WS</u>, <u>Hong JR</u>, <u>Son T</u>, <u>Chang SK</u>, <u>Lee M</u>. In vitro assessment of clastogenicity of mobile-phone radiation (835 MHz) using the alkaline comet assay and chromosomal aberration test. <u>Environ Toxicol.</u> 23(3):319-327, 2008.
Recently we demonstrated that 835-MHz radiofrequency radiation electromagnetic fields (RF-EMF) neither affected the reverse mutation frequency nor accelerated DNA degradation in vitro. Here, two kinds of cytogenetic endpoints were further investigated on mammalian cells exposed to 835-MHz RF-EMF (the most widely used communication frequency band in Korean CDMA mobile phone networks) alone and in combination with model clastogens: in vitro alkaline comet assay and in vitro chromosome aberration (CA) test. No direct cytogenetic effect of 835-MHz RF-EMF was found in the in vitro CA test. The combined exposure of the cells to RF-EMF in the presence of ethylmethanesulfonate (EMS) revealed a weak and insignificant cytogenetic effect when compared to cells exposed to EMS alone in CA test. Also, the comet assay results to evaluate the ability of RF-EMF alone to damage DNA were nearly negative, although showing a small increase in tail moment. However, the applied RF-EMF had potentiation

effect in comet assay when administered in combination with model clastogens (cyclophosphamide or 4-nitroquinoline 1-oxide). Thus, our results imply that we cannot confidently exclude any possibility of an increased risk of genetic damage, with important implications for the possible health effects of exposure to 835-MHz electromagnetic fields.

Nikolova T, Czyz J, Rolletschek A, Blyszczuk P, Fuchs J, Jovtchev G, Schuderer J, Kuster N, Wobus AM. Electromagnetic fields affect transcript levels of apoptosis-related genes in embryonic stem cell-derived neural progenitor cells. ASEB J. 19(12):1686-1688, 2005.
Mouse embryonic stem (ES) cells were used as an experimental model to study the effects of electromagnetic fields (EMF). ES-derived nestin-positive neural progenitor cells were exposed to extremely low frequency EMF simulating power line magnetic fields at 50 Hz (ELF-EMF) and to radiofrequency EMF simulating the Global System for Mobile Communication (GSM) signals at 1.71 GHz (RF-EMF). Following EMF exposure, cells were analyzed for transcript levels of cell cycle regulatory, apoptosis-related, and neural-specific genes and proteins; changes in proliferation; apoptosis; and cytogenetic effects. Quantitative RT-PCR analysis revealed that ELF-EMF exposure to ES-derived neural cells significantly affected transcript levels of the apoptosis-related bcl-2, bax, and cell cycle regulatory "growth arrest DNA damage inducible" GADD45 genes, whereas mRNA levels of neural-specific genes were not affected. RF-EMF exposure of neural progenitor cells resulted in down-regulation of neural-specific Nurr1 and in up-regulation of bax and GADD45 mRNA levels. Short-term RF-EMF exposure for 6 h, but not for 48 h, resulted in a low and transient increase of DNA double-strand breaks. No effects of ELF- and RF-EMF on mitochondrial function, nuclear apoptosis, cell proliferation, and chromosomal alterations were observed. We may conclude that EMF exposure of ES-derived neural progenitor cells transiently affects the transcript level of genes related to apoptosis and cell cycle control. However, these responses are not associated with detectable changes of cell physiology, suggesting compensatory mechanisms at the translational and posttranslational level.

Maes A, Collier M, Slaets D, Verschaeve L, 954 MHz microwaves enhance the mutagenic properties of mitomycin C. Environ Mol Mutagen 28(1):26-30, 1996.
This paper focuses on the combined effects of microwaves from mobile communication frequencies and a chemical DNA damaging agent mitomycin C (MMC). The investigation was performed in vitro by exposing whole blood samples to a 954 MHz emitting antenna from a GSM (Global System for Mobile Communication) base station, followed by lymphocyte cultivation in the presence of MMC. A highly reproducible synergistic effect was observed as based on the frequencies of sister chromatid exchanges in metaphase figures.

Fritze K, Wiessner C, Kuster N, Sommer C, Gass P, Hermann DM, Kiessling M,Hossmann KA, Effect of global system for mobile communication microwave exposure on the genomic response of the rat brain. Neuroscience 81(3):627-639, 1997.

The acute effect of global system for mobile communication (GSM) microwave exposure on the genomic response of the central nervous system was studied in rats by measuring changes in the messenger RNAs of hsp70, the transcription factor genes c-fos and c-jun and the glial structural gene GFAP using in situ hybridization histochemistry. Protein products of transcription factors, stress proteins and marker proteins of astroglial and microglial activation were assessed by immunocytochemistry. Cell proliferation was evaluated by bromodeoxyuridine incorporation. A special GSM radiofrequency test set, connected to a commercial cellular phone operating in the discontinuous transmission mode, was used to simulate GSM exposure. The study was conducted at time averaged and brain averaged specific absorption rates of 0.3 W/kg (GSM exposure), 1.5 W/kg (GSM exposure) and 7.5 W/kg (continuous wave exposure), respectively. Immediately after exposure, in situ hybridization revealed slight induction of hsp70 messenger RNA in the cerebellum and hippocampus after 7.5 W/kg exposure, but not at lower intensities. A slightly increased expression of c-fos messenger RNA was observed in the cerebellum, neocortex and piriform cortex of all groups subjected to immobilization, but no differences were found amongst different exposure conditions. C-jun and GFAP messenger RNAs did not increase in any of the experimental groups. 24 h after exposure, immunocytochemical analysis of FOS and JUN proteins (c-FOS, FOS B, c-JUN JUN B, JUN D), of HSP70 or of KROX-20 and -24 did not reveal any alterations. Seven days after exposure, neither increased cell proliferation nor altered expression of astroglial and microglial marker proteins were observed. In conclusion, acute high intensity microwave exposure of immobilized rats may induce some minor stress response but does not result in lasting adaptive or reactive changes of the brain.

Baohong Wang, Jiliang H, Lifen J, Deqiang L, Wei Z, Jianlin L, Hongping D. Studying the synergistic damage effects induced by 1.8GHz radiofrequency field radiation (RFR) with four chemical mutagens on human lymphocyte DNA using comet assay in vitro. Mutat Res. 578(1-2):149-157, 2005.

The aim of this investigation was to study the synergistic DNA damage effects in human lymphocytes induced by 1.8GHz radiofrequency field radiation (RFR, SAR of 3W/kg) with four chemical mutagens, i.e. mitomycin C (MMC, DNA crosslinker), bleomycin (BLM, radiomimetic agent), methyl methanesulfonate (MMS, alkylating agent), and 4-nitroquinoline-1-oxide (4NQO, UV-mimetic agent). The DNA damage of lymphocytes exposed to RFR and/or with chemical mutagens was detected at two incubation time (0 or 21h) after treatment with comet assay in vitro. Three combinative exposure ways were used. Cells were exposed to RFR and chemical mutagens for 2 and 3h, respectively. Tail length (TL) and tail moment (TM) were utilized as DNA damage indexes. The results showed no difference of DNA damage indexes between RFR group and control group at 0 and 21h incubation after exposure (P>0.05). There were significant difference of DNA damage indexes between MMC group and RFR+MMC co-exposure group at 0 and 21h incubation after treatment (P<0.01). Also the significant difference of DNA damage indexes between 4NQO group and RFR+4NQO co-exposure group at 0 and 21h incubation after treatment was observed (P<0.05 or P<0.01). The DNA damage in RFR+BLM co-exposure groups and RFR+MMS co-exposure groups was not significantly

increased, as compared with corresponding BLM and MMS groups (P>0.05). The experimental results indicated 1.8GHz RFR (SAR, 3W/kg) for 2h did not induce the human lymphocyte DNA damage effects in vitro, but could enhance the human lymphocyte DNA damage effects induced by MMC and 4NQO. The synergistic DNA damage effects of 1.8GHz RFR with BLM or MMS were not obvious.

Baohong W, Lifen J, Lanjuan L, Jianlin L, Deqiang L, Wei Z, Jiliang H.Evaluating the combinative effects on human lymphocyte DNA damage induced by ultraviolet ray C plus 1.8GHz microwaves using comet assay in vitro.Toxicology. 232(3):311-316, 2007.
The objective of this study was to observe whether 1.8GHz microwaves (MW) (SAR, 3 W/kg) exposure can influence human lymphocyte DNA damage induced by ultraviolet ray C (UVC). The lymphocytes, which were from three young healthy donors, were exposed to 254 nm UVC at the doses of 0.25, 0.5, 0.75, 1.0, 1.5 and 2.0 J m(-2), respectively. The lymphocytes were irradiated by 1.8GHz MW (SAR, 3 W/kg) for 0, 1.5 and 4 h. The combinative exposure of UVC plus MW was conducted. The treated cells were incubated for 0, 1.5 and 4 h. Finally, comet assay was used to measure DNA damage of above treated lymphocytes. The results indicated that the difference of DNA damage induced between MW group and control group was not significant (P>0.05). The MTLs induced by UVC were 1.71+/-0.09, 2.02+/-0.08, 2.27+/-0.17, 2.27+/-0.06, 2.25+/-0.12, 2.24+/-0.11 microm, respectively, which were significantly higher than that (0.96+/-0.05 microm) of control (P<0.01). MTLs of some sub-groups in combinative exposure groups at 1.5-h incubation were significantly lower that those of corresponding UVC sub-groups (P<0.01 or P<0.05). However, MTLs of some sub-groups in combinative exposure groups at 4-h incubation were significantly higher that those of corresponding UVC sub-groups (P<0.01 or P<0.05). In this experiment it was found that 1.8GHz (SAR, 3 W/kg) MW exposure for 1.5 and 4 h did not enhance significantly human lymphocyte DNA damage, but could reduce and increase DNA damage of human lymphocytes induced by UVC at 1.5-h and 4-h incubation, respectively.

Canseven AG, Esmekaya MA, Kayhan H, Tuysuz MZ, Seyhan N. Effects of microwave exposure and Gemcitabine treatment on apoptotic activity in Burkitt's lymphoma (Raji) cells. Electromagn Biol Med. 2014 Jun 5:1-5. [Epub ahead of print]
We investigated the effects of 1.8 MHz Global System for Mobile Communications (GSM)-modulated microwave (MW) radiation on apoptotic level and cell viability of Burkitt's lymphoma (Raji) cells with or without Gemcitabine, which exhibits cell phase specificity, primarily killing cells undergoing DNA synthesis (S-phase). Raji cells were exposed to 1.8 GHz GSM-modulated MW radiation at a specific absorption rate (SAR) of 0.350 W/kg in a CO_2 incubator. The duration of the exposure was 24 h. The amount of apoptotic cells was analyzed using Annexin V-FITC and propidium iodide (PI) staining with flow cytometer. The apoptotic activity of MW exposed Raji cells was increased significantly. In addition, cell viability of exposed samples was significantly decreased. Combined exposure of MW and Gemcitabine increased the amount of apoptotic cells than MW radiation alone. Moreover, viability of MW + Gemcitabine exposed cells was lower than that of cells exposed only to MW. These results demonstrated that MW

radiation exposure and Gemcitabine treatment have a synergistic effect on apoptotic activity of Raji cells.

Effects on Glands

Aydogan F, Unlu I, Aydin E, Yumusak N, Devrim E, Samim EE, Ozgur E, Unsal V, Tomruk A, Ozturk GG, Seyhan N. The effect of 2100 MHz radiofrequency radiation of a 3G mobile phone on the parotid gland of rats. Am J Otolaryngol. 2014 Oct 5. pii: S0196-0709(14)00207-5. doi: 10.1016/j.amjoto.2014.10.001. [Epub ahead of print]

PURPOSE: We aimed to evaluate the effect of 2100 MHz radiofrequency radiation on the parotid gland of rats in short and relatively long terms. MATERIAL AND METHODS: Thirty Wistar albino rats were divided into four groups. Groups A and B served as the control groups (for 10 days and 40 days, respectively), and each group included six rats. Groups C and D were composed of nine rats each, and they were the exposure groups. The rats were exposed to 2100 MHz radiofrequency radiation emitted by a generator, simulating a third generation mobile phone for 6 hours/day, 5 days/week, for 10 or 40 days. Following exposure, the rats were sacrificed and parotid glands were removed. Histopathological and biochemical examinations were performed. RESULTS: Although there were no histopathological changes in the control groups except for two animals in group A and three animals in group B, the exposure groups C (10 days) and D (40 days) showed numerous histopathological changes regarding salivary gland damage including acinar epithelial cells, interstitial space, ductal system, vascular system, nucleus, amount of cytoplasm and variations in cell size. The histopathological changes were more prominent in group D compared to group C. There was statistically significant different parameter regarding variation in cell size between the groups B and D (p=0.036). CONCLUSION: The parotid gland of rats showed numerous histopathological changes after exposure to 2100 MHz radiofrequency radiation, both in the short and relatively long terms. Increased exposure duration led to an increase in the histopathological changes.

Effects on Animals and Environment

Panagopoulos DJ, Chavdoula ED, Margaritis LH. Bioeffects of mobile telephony radiation in relation to its intensity or distance from the antenna. Int J Radiat Biol. 86(5):345-357, 2010.
PURPOSE: To examine the bioactivity of GSM 900 and 1800 (Global System for Mobile Telecommunications) radiations, in relation to the distance from the antenna or to the radiation-field intensities. MATERIALS AND METHODS: Drosophila melanogaster adult insects were exposed to the radiation of a GSM 900/1800 mobile phone antenna at different distances ranging from 0 to 100 cm, and the effect on their reproductive capacity and cell death induction in the gonads by the use of TUNEL (Terminal

deoxynucleotide transferase dUTP Nick End Labeling) assay, was studied. RESULTS: These radiations/fields decreased the reproductive capacity by cell death induction, at all the different distances tested. The effect diminished with the distance/decreasing intensities. An increased bioactivity 'window' was revealed at distances of 20-30 cm from the mobile phone antenna, (radiation intensity around 10 microW/cm(2)) where the effect became highest, in relation to smaller or longer distances. The effect diminished considerably for distances longer than 40-50 cm and became not evident for distances longer than 1 m or radiation intensities smaller than 1 microW/cm(2). CONCLUSIONS: GSM bioactivity is highest for intensities down to less than 10 microW/cm(2) and still evident until 1 microW/cm(2) exhibiting 'window' effects

Loscher W, Kas G, Extraordinary behavior disorders in cows in proximity to transmission stations. Der Praktische Tierarz 79:437-444, 1998. (Article in German)
In addition to reduction of milk yield and increased health problems, behavioral abnormalities were observed over a period of two years in a herd of diary cows maintained in close proximity to a TV and cell phone transmitting antenna. Evaluation of possible factors which could explain the abnormalities in the live stock did not disclose any factors other than the high-frequency electromagnetic fields. An experiment in which a cow with abnormal behavior was brought to a stable 20 km away from the antenna resulted in a complete normalization of the cow within five days, whereas symptoms returned when the cow was brought back to the stable nearby the antenna. In view of the previous described effects of electromagnetic fields, it might be possible that the observed abnormalities in cows are related to electromagnetic field exposure. (power densities measured 0.02-7 mW/m2).

Koldayev VM, Shchepin YV, Effects of electromagnetic radiation on embryos of sea-urchins. Bioelectrochem Bioenerg 43:161-164, 1997.
Electromagnetic radiation (EMR) causes a decrease in the number of fertilized eggs and an increase in the number of zygotes with abnormal fertilization envelopes in sea-urchins. The microstructural impairments of the cellular surface, the increase of lipid peroxidation and the changes of amino acid metabolism show that the impairments of the development of embryos exposed to EMR are caused by the damages of the membrane structures.

Cammaerts MC, De Doncker P, Patris X, Bellens F, Rachidi Z, Cammaerts D. GSM 900 MHz radiation inhibits ants' association between food sites and encountered cues. Electromagn Biol Med. 31(2):151-165, 2012.
The kinetics of the acquisition and loss of the use of olfactory and visual cues were previously obtained in six experimental colonies of the ant Myrmica sabuleti meinert 1861, under normal conditions. In the present work, the same experiments were conducted on six other naive identical colonies of M. sabuleti, under electromagnetic radiation similar to those surrounding GSM and communication masts. In this situation, no association between food and either olfactory or visual cues occurred. After a recovery period, the ants were able to make such an association but never reached the

expected score. Such ants having acquired a weaker olfactory or visual score and still undergoing olfactory or visual training were again submitted to electromagnetic waves. Not only did they lose all that they had memorized, but also they lost it in a few hours instead of in a few days (as under normal conditions when no longer trained). They kept no visual memory at all (instead of keeping 10% of it as they normally do). The impact of GSM 900 MHz radiation was greater on the visual memory than on the olfactory one. These communication waves may have such a disastrous impact on a wide range of insects using olfactory and/or visual memory, i.e., on bees.

Senavirathna MD, Asaeda T, Thilakarathne BL, Kadono H. Nanometer-scale elongation rate fluctuations in the Myriophyllum aquaticum (Parrot feather) stem were altered by radio-frequency electromagnetic radiation. Plant Signal Behav. 2014 Mar 26;9(3). pii: e28590. [Epub ahead of print]
The emission of radio-frequency electromagnetic radiation (EMR) by various wireless communication base stations has increased in recent years. While there is wide concern about the effects of EMR on humans and animals, the influence of EMR on plants is not well understood. In this study, we investigated the effect of EMR on the growth dynamics of Myriophyllum aquaticum (Parrot feather) by measuring the nanometric elongation rate fluctuation (NERF) using a statistical interferometry technique. Plants were exposed to 2 GHz EMR at a maximum of 1.42 Wm-2 for 1 h. After continuous exposure to EMR, M. aquaticum plants exhibited a statistically significant 51 ± 16% reduction in NERF standard deviation. Temperature observations revealed that EMR exposure did not cause dielectric heating of the plants. Therefore, the reduced NERF was due to a non-thermal effect caused by EMR exposure. The alteration in NERF continued for at least 2.5 h after EMR exposure and no significant recovery was found in post-EMR NERF during the experimental period.

Balmori A. Mobile Phone Mast Effects on Common Frog (Rana temporaria) Tadpoles: The City Turned into a Laboratory. Electromagn Biol Med. 29(1-2):31-35, 2010.
An experiment has been made exposing eggs and tadpoles of the common frog (Rana temporaria) to electromagnetic radiation from several mobile (cell) phone antennae located at a distance of 140 meters. The experiment lasted two months, from the egg phase until an advanced phase of tadpole prior to metamorphosis. Measurements of electric field intensity (radiofrequencies and microwaves) in V/m obtained with three different devices were 1.8 to 3.5 V/m. In the exposed group (n = 70), low coordination of movements, an asynchronous growth, resulting in both big and small tadpoles, and a high mortality (90%) was observed. Regarding the control group (n = 70) under the same conditions but inside a Faraday cage, the coordination of movements was normal, the development was synchronous, and a mortality of 4.2% was obtained. These results indicate that radiation emitted by phone masts in a real situation may affect the development and may cause an increase in mortality of exposed tadpoles. This research may have huge implications for the natural world, which is now exposed to high microwave radiation levels from a multitude of phone masts.

Balode, Z, Assessment of radio-frequency electromagnetic radiation by the micronucleus test in bovine peripheral erythrocytes. Sci Total Environ 180(1):81-85, 1996.
Previous bioindicative studies in the Skrunda Radio Location Station area have focused on the somatic influence of electromagnetic radiation on plants, but it is also important to study genetic effects. We have chosen cows as test animals for cytogenetical evaluation because they live in the same general exposure area as humans, are confined to specific locations and are chronically exposed to radiation. Blood samples were obtained from female Latvian Brown cows from a farm close to and in front of the Skrunda Radar and from cows in a control area. A simplified alternative to the Schiff method of DNA staining for identification of micronuclei in peripheral erythrocytes was applied. Microscopically, micronuclei in peripheral blood erythrocytes were round in shape and exhibited a strong red colour. They are easily detectable as the only coloured bodies in the uncoloured erythrocytes. From each individual animal 2000 erythrocytes were examined at a magnification of x 1000 for the presence of micronuclei. The counting of micronuclei in peripheral erythrocytes gave low average incidences, 0.6 per 1000 in the exposed group and 0.1 per 1000 in the control, but statistically significant (P < 0.01) differences were found in the frequency distribution between the control and exposed groups.

Effects on Skin

Cam ST, Seyhan N, Kavaklı C, Celikbıçak O. Effects of 900 MHz Radiofrequency Radiation on Skin Hydroxyproline Contents. Cell Biochem Biophys. 2014 Apr 24. [Epub ahead of print]
The present study aimed to investigate the possible effect of pulse-modulated radiofrequency radiation (RFR) on rat skin hydroxyproline content, since skin is the first target of external electromagnetic fields. Skin hydroxyproline content was measured using liquid chromatography mass spectrometer method. Two months old male wistar rats were exposed to a 900 MHz pulse-modulated RFR at an average whole body specific absorption rate (SAR) of 1.35 W/kg for 20 min/day for 3 weeks. The radiofrequency (RF) signals were pulse modulated by rectangular pulses with a repetition frequency of 217 Hz and a duty cycle of 1:8 (pulse width 0.576 ms). A skin biopsy was taken at the upper part of the abdominal costa after the exposure. The data indicated that whole body exposure to a pulse-modulated RF radiation that is similar to that emitted by the global system for mobile communications (GSM) mobile phones caused a statistically significant increase in the skin hydroxyproline level (p = 0.049, Mann-Whitney U test). Under our experimental conditions, at a SAR less than the International Commission on Non-Ionizing Radiation Protection safety limit recommendation, there was evidence that GSM signals could alter hydroxyproline concentration in the rat skin.

Effects on Protein

Hässig M, Wullschleger M, Naegeli HP, Kupper J, Spiess B, Kuster N, Capstick M, Murbach M. Influence of non ionizing radiation of base stations on the activity of redox proteins in bovines. BMC Vet Res. 2014 Jun 19;10(1):136. [Epub ahead of print]
BACKGROUND: The influence of electromagnetic fields on the health of humans and animals is still an intensively discussed and scientifically investigated issue (Prakt Tierarzt 11:15-20, 2003; Umwelt Medizin Gesellschaft 17:326-332, 2004; J Toxicol Environment Health, Part B 12:572-597, 2009). We are surrounded by numerous electromagnetic fields of variable strength, coming from electronic equipment and its power cords, from high-voltage power lines and from antennas for radio, television and mobile communication. Particularly the latter cause's controversy, as everyone likes to have good mobile reception at anytime and anywhere, whereas nobody wants to have such a base station antenna in their proximity. RESULTS: In this experiment, the **non-ionizing radiation (NIR)** has resulted in changes in the enzyme activities. Certain enzymes were disabled, others enabled by NIR. Furthermore, individual behavior patterns were observed. While certain cows reacted to NIR, others did not react at all, or even inversely. CONCLUSION: The present results coincide with the information from the literature, according to which NIR leads to changes in redox proteins, and that there are individuals who are sensitive to radiation and others that are not. However, the latter could not be distinctly attributed - there are cows that react clearly with one enzyme while they do not react with another enzyme at all, or even the inverse. The study approach of testing ten cows each ten times during three phases has proven to be appropriate. Future studies should however set the post-exposure phase later on.

Effects on Immune Function

Li CY, Liao MH, Lin CW, Tsai WS, Huang CC, Tang TK. Inhibitory Effects of Microwave Radiation on LPS-Induced NFκB Expression in THP-1 Monocytes. Chin J Physiol. 55(6):421-427, 2012.
Microwave radiations can be encountered regularly in daily lives. When WHO announced that microwave radiations were a kind of environmental energy which interfere with the physiological functions of the human body, great concerns have been raised over the damages microwave frequencies can do to human physiology. The immunological performance and the activities of the cellular inflammatory factor NFκB have been closely related in monocyte. Due to the effect of phorbol 12-myristate 13-acetate (PMA) on THP-1 monocytes, THP-1 monocytes would differentiate into macrophages and would then react with lipopolysaccharides (LPS), and the amount of NFκB increased in the THP-1 monocytes. Expression of cytokine is affected when cells are exposed to a frequency of 2450 MHz and at 900 W. Thus, in our experiments, an observation was made when THP-1 monocytes were stimulated with PMA and LPS to differentiate into macrophage, the amount of NFκB in cells increased exponentially, and

the levels of NFκB expression were decreased by the exposure of microwave radiation. In conclusion, microwave radiations were found to inhibit the activity functions of THP-1 monocytes stimulated with PMA and LPS.

Electro Hypersensitivity

Nordin S, Neely G, Olsson D, Sandström M. Odor and Noise Intolerance in Persons with Self-Reported Electromagnetic Hypersensitivity. Int J Environ Res Public Health. 11(9):8794-8805, 2014.
Lack of confirmation of symptoms attributed to electromagnetic fields (EMF) and triggered by EMF exposure has highlighted the role of individual factors. Prior observations indicate intolerance to other types of environmental exposures among persons with electromagnetic hypersensitivity (EHS). This study assessed differences in odor and noise intolerance between persons with EHS and healthy controls by use of subscales and global measures of the Chemical Sensitivity Scale (CSS) and the Noise Sensitivity Scale (NSS). The EHS group scored significantly higher than the controls on all CSS and NSS scales. Correlation coefficients between CSS and NSS scores ranged from 0.60 to 0.65 across measures. The findings suggest an association between EHS and odor and noise intolerance, encouraging further investigation of individual factors for understanding EMF-related symptoms.

RF Levels in Cities

Urbinello D, Huss A, Beekhuizen J, Vermeulen R, Röösli M. Use of portable exposure meters for comparing mobile phone base station radiation in different types of areas in the cities of Basel and Amsterdam. Sci Total Environ. 468-469:1028-1033, 2014.

BACKGROUND: Radiofrequency electromagnetic fields (RF-EMF) are highly variable and differ considerably within as well as between areas. Exposure assessment studies characterizing spatial and temporal variation are limited so far. Our objective was to evaluate sources of data variability and the repeatability of daily measurements using portable exposure meters (PEMs). METHODS: Data were collected at 12 days between November 2010 and January 2011 with PEMs in four different types of urban areas in the cities of Basel (BSL) and Amsterdam (AMS). RESULTS: Exposure from mobile phone base stations ranged from 0.30 to 0.53 V/m in downtown and business areas and in residential areas from 0.09 to 0.41 V/m. Analysis of variance (ANOVA) demonstrated that measurements from various days were highly reproducible (measurement duration of approximately 30 min) with only 0.6% of the variance of all measurements from mobile phone base station radiation being explained by the measurement day and only 0.2% by the measurement time (morning, noon, afternoon), whereas type of area (30%) and city (50%) explained most of the data variability. CONCLUSIONS: We conclude that mobile monitoring of exposure from mobile phone base station radiation with PEMs is

useful due to the high repeatability of mobile phone base station exposure levels, despite the high spatial variation.

Urbinello D, Joseph W, Verloock L, Martens L, Röösli M. Temporal trends of radio-frequency electromagnetic field (RF-EMF) exposure in everyday environments across European cities. Environ Res. 2014 Aug 12;134C:134-142. doi: 10.1016/j.envres.2014.07.003. [Epub ahead of print]
BACKGROUND: The rapid development and increased use of wireless telecommunication technologies led to a substantial change of radio-frequency electromagnetic field (RF-EMF) exposure in the general population but little is known about temporal trends of RF-EMF in our everyday environment. OBJECTIVES: The objective of our study is to evaluate temporal trends of RF-EMF exposure levels in different microenvironments of three European cities using a common measurement protocol. METHODS: We performed measurements in the cities of Basel (Switzerland), Ghent and Brussels (Belgium) during one year, between April 2011 and March 2012. RF-EMF exposure in 11 different frequency bands ranging from FM (Frequency Modulation, 88MHz) to WLAN (Wireless Local Area Network, 2.5GHz) was quantified with portable measurement devices (exposimeters) in various microenvironments: outdoor areas (residential areas, downtown and suburb), public transports (train, bus and tram or metro rides) and indoor places (airport, railway station and shopping centers). Measurements were collected every 4s during 10-50min per environment and measurement day. Linear temporal trends were analyzed by mixed linear regression models. RESULTS: Highest total RF-EMF exposure levels occurred in public transports (all public transports combined) with arithmetic mean values of 0.84V/m in Brussels, 0.72V/m in Ghent, and 0.59V/m in Basel. In all outdoor areas combined, mean exposure levels were 0.41V/m in Brussels, 0.31V/m in Ghent and 0.26V/m in Basel. Within one year, total RF-EMF exposure levels in all outdoor areas in combination increased by 57.1% (p<0.001) in Basel by 20.1% in Ghent (p=0.053) and by 38.2% (p=0.012) in Brussels. Exposure increase was most consistently observed in outdoor areas due to emissions from mobile phone base stations. In public transports RF-EMF levels tended also to increase but mostly without statistical significance. DISCUSSION: An increase of RF-EMF exposure levels has been observed between April 2011 and March 2012 in various microenvironments of three European cities. Nevertheless, exposure levels were still far below regulatory limits of each country. A continuous monitoring is needed to identify high exposure areas and to anticipate critical development of RF-EMF exposure at public places.

Estenberg J, Augustsson T. Extensive frequency selective measurements of radiofrequency fields in outdoor environments performed with a novel mobile monitoring system. Bioelectromagnetics. 2013 Dec 27. doi: 10.1002/bem.21830. [Epub ahead of print]
A novel, car based, measuring system for estimation of general public outdoor exposure to radiofrequency fields (RF) has been developed. The system enables fast, large area, isotropic spectral measurements with a bandwidth covering the frequency range of

30 MHz to 3 GHz. Measurements have shown that complete mapping of a town with 15000 inhabitants and a path length of 115 km is possible to perform within 1 day. The measured areas were chosen to represent typical rural, urban and city areas of Sweden. The data sets consist of more than 70000 measurements. All measurements were performed during the daytime. The median power density was 16 $\mu W/m^2$ in rural areas, 270 $\mu W/m^2$ in urban areas, and 2400 $\mu W/m^2$ in city areas. <u>In urban and city areas, base stations for mobile phones were clearly the dominating sources of exposure.</u>

Effects on Water

Hinrikus H, Lass J, Karai D, Pilt K, Bachmann M. Microwave effect on diffusion: a possible mechanism for non-thermal effect. Electromagn Biol Med. 23:1-7, 2014.
In this study, we assume that microwave radiation affects hydrogen bonding between dipolar water molecules and through that diffusion in water at constant temperature. The experimental study was performed on the setup of two identical reservoirs filled with pure water and 0.9% NaCl solution and connected by a thin tube. Alterations of NaCl concentration in the reservoir initially filled with pure water were measured using the resistance of the solution as an indicator. The applied 450 MHz continuous-wave microwave field had the maximal specific absorption rate of 0.4 W/kg on the connecting tube. The standard deviation of water temperature in the setup was 0.02 °C during an experiment. Our experimental data demonstrated that microwave exposure makes faster the process of diffusion in water. The time required for reduction of initial resistance of the solution by 10% was 1.7 times shorter with microwave. <u>This result is consistent with the proposed mechanism of low-level microwave effect: microwave radiation, rotating dipolar water molecules, causes high-frequency alterations of hydrogen bonds between water molecules, thereby affects its viscosity and makes faster diffusion.</u>

RF Levels From Cell Towers

<u>Martinez-Burdalo M</u>, <u>Martin A</u>, <u>Anguiano M</u>, <u>Villar R</u>. On the safety assessment of human exposure in the proximity of cellular communications base-station antennas at 900, 1800 and 2170 MHz. Phys Med Biol. 50(17):4125-4137, 2005.
In this work, the procedures for safety assessment in the close proximity of cellular communications base-station antennas at three different frequencies (900, 1800 and 2170 MHz) are analysed. For each operating frequency, we have obtained and compared the distances to the antenna from the exposure places where electromagnetic fields are below reference levels and the distances where the specific absorption rate (SAR) values in an exposed person are below the basic restrictions, according to the European safety guidelines. A high-resolution human body model has been located, in front of each base-station antenna as a worst case, at different distances, to compute whole body averaged SAR and maximum 10 g averaged SAR

inside the exposed body. The finite-difference time-domain method has been used for both electromagnetic fields and SAR calculations. This paper shows that, for antenna-body distances in the near zone of the antenna, the fact that averaged field values be below the reference levels could, at certain frequencies, not guarantee guidelines compliance based on basic restrictions.

Hu J, Lu Y, Zhang H, Xie H, Yang X. [Level of microwave radiation from mobile phone base stations built in residential districts] Wei Sheng Yan Jiu. 38(6):712-716, 2009.
[Article in Chinese]
OBJECTIVE: To investigate the condition of microwave radiation pollution from mobile phone base station built in populated area. METHODS: Random selected 18 residential districts where had base station and 10 residential districts where had no base stations. A TES-92 electromagnetic radiation monitor were used to measure the intensity of microwave radiation in external and internal living environment. RESULTS: The intensities of microwave radiation in the exposure residential districts were more higher than those of the control residential districts ($p < 0.05$). There was a intensity peak at about 10 m from the station, it would gradually weaken with the increase of the distance. The level of microwave radiation in antenna main lobe region is not certainly more higher than the side lobe direction, and the side lobe direction also is not more lower. At the same district, where there were two base stations, the electromagnetic field nestification would take place in someplace. The intensities of microwave radiation outside the exposure windows in the resident room not only changed with distance but also with the height of the floor. The intensities of microwave radiation inside the aluminum alloys security net were more lower than those of outside the aluminum alloys security net ($p < 0.05$), but the inside or outside of glass-window appears almost no change ($p > 0.05$). CONCLUSIONS: Although all the measure dates on the ground around the base station could be below the primary standard in "environment electromagnetic wave hygienic standard" (GB9175-88), there were still a minorities of windows which exposed to the base station were higher, and the outside or inside of a few window was even higher beyond the primary safe level defined standard. The aluminum alloys security net can partly shield the microwave radiation from the mobile phone base station.

Danger Perception and Symptoms

Hutter HP, Moshammer H, Wallner P, Kundi M. Public perception of risk concerning cell towers and mobile phones. Soz Praventivmed. 49(1):62-66, 2004.
OBJECTIVE: The controversy about health risks of electromagnetic fields (EMF) has contributed in raising fears concerning emissions from celltowers. The study was to examine whether or not neighbours of celltowers are particularly concerned about adverse health effects of mobile phones and their base stations. METHODS: Prior to information delivered by medical doctors of the Institute of Environmental Health at public hearings a questionnaire was handed out to participants asking for their personal

rating of several environmental health risks including those of mobile telecommunication (n = 123, response rate approx. 48%). Medical students (n = 366) served as a contrast group. RESULTS: Participants rated health risk for both, mobile phones and celltowers higher as students. A trend for higher ratings was also seen with older subjects and female sex. The risk ratings of both exposures correlated well with each other. The magnitude of the perceived risks, however, resembled that of other ubiquitous exposures like traffic noise and air pollution. <u>CONCLUSION: Contrary to the claims of the telecommunication industry, opponents of celltowers generally do not express unusual fears concerning electromagnetic field exposure. The outcome of our study indicates that the risk rating is comparable with other perceived common hazards of the civilised world. It is hypothesised that offering information and participation to the concerned population will be efficient in reducing exaggerated fears.</u>

Reason Why Not A Lot Of Studies on Cell Towers

Kundi M, Hutter HP.Mobile phone base stations-Effects on wellbeing and health.Pathophysiology. 16(2-3):123-135, 2009.
Studying effects of mobile phone base station signals on health have been discouraged by authoritative bodies like WHO International EMF Project and COST 281. WHO recommended studies around base stations in 2003 but again stated in 2006 that studies on cancer in relation to base station exposure are of low priority. As a result only few investigations of effects of base station exposure on health and wellbeing exist. Cross-sectional investigations of subjective health as a function of distance or measured field strength, despite differences in methods and robustness of study design, found indications for an effect of exposure that is likely independent of concerns and attributions. Experimental studies applying short-term exposure to base station signals gave various results, but there is weak evidence that UMTS and to a lesser degree GSM signals reduce wellbeing in persons that report to be sensitive to such exposures. Two ecological studies of cancer in the vicinity of base stations report both a strong increase of incidence within a radius of 350 and 400m respectively. Due to the limitations inherent in this design no firm conclusions can be drawn, but the results underline the urgent need for a comprehensive investigation of this issue. Animal and in vitro studies are inconclusive to date. An increased incidence of DMBA induced mammary tumors in rats at a SAR of 1.4W/kg in one experiment could not be replicated in a second trial. Indications of oxidative stress after low-level in vivo exposure of rats could not be supported by in vitro studies of human fibroblasts and glioblastoma cells. From available evidence it is impossible to delineate a threshold below which no effect occurs, however, given the fact that studies reporting low exposure were invariably negative it is suggested that power densities around 0.5-1mW/m(2) must be exceeded in order to observe an effect. The meager data base must be extended in the coming years. The difficulties of investigating long-term effects of base station exposure have been exaggerated, considering that base station and handset exposure have almost nothing

in common both needs to be studied independently. It cannot be accepted that studying base stations is postponed until there is firm evidence for mobile phones.

Miscellaneous Effects

Panagopoulos, D. J., Johansson O. & Carlo G.L. Polarization: A Key Difference between Man-made and Natural Electromagnetic Fields, in regard to Biological Activity. *Sci. Rep*. 5, 14914; doi: 10.1038/srep14914 (2015). Published online Oct 12, 2015.
In the present study we analyze the role of polarization in the biological activity of Electromagnetic Fields (EMFs)/Electromagnetic Radiation (EMR). All types of man-made EMFs/EMR - in contrast to natural EMFs/EMR - are polarized. Polarized EMFs/EMR can have increased biological activity, due to: 1) Ability to produce constructive interference effects and amplify their intensities at many locations. 2) Ability to force all charged/polar molecules and especially free ions within and around all living cells to oscillate on parallel planes and in phase with the applied polarized field. Such ionic forced-oscillations exert additive electrostatic forces on the sensors of cell membrane electro-sensitive ion channels, resulting in their irregular gating and consequent disruption of the cell's electrochemical balance. These features render man-made EMFs/EMR more bioactive than natural non-ionizing EMFs/EMR. This explains the increasing number of biological effects discovered during the past few decades to be induced by man-made EMFs, in contrast to natural EMFs in the terrestrial environment which have always been present throughout evolution, although human exposure to the latter ones is normally of significantly higher intensities/energy and longer durations. Thus, polarization seems to be a trigger that significantly increases the probability for the initiation of biological/health effects.

Dhami AK. Study of electromagnetic radiation pollution in an Indian city. Environ Monit Assess.184(11):6507-6512, 2012.
Abstract. Electromagnetic radiation emitted by cell phone towers is a form of environmental pollution and is a new health hazard, especially to children and patients. The present studies were taken to estimate the microwave/RF pollution by measuring radiation power densities near schools and hospitals of Chandigarh city in India. The cell phone radiations were measured using a handheld portable power density meter TES 593 and specific absorption rates were estimated from the measured values. These values of electromagnetic radiation in the environment were compared with the levels at which biological system of humans and animals starts getting affected. The values were also compared with the international exposure limits set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The highest measured power density was 11.48 mW/m(2) which is 1,148% of the biological limit. The results indicated that the exposure levels in the city were below the ICNIRP limit, but much above the biological limit.

Cell Towers; Consequences of Chronic Microwave RF Expsosure,
Dr. Paul Dart MD. (Petitioner)

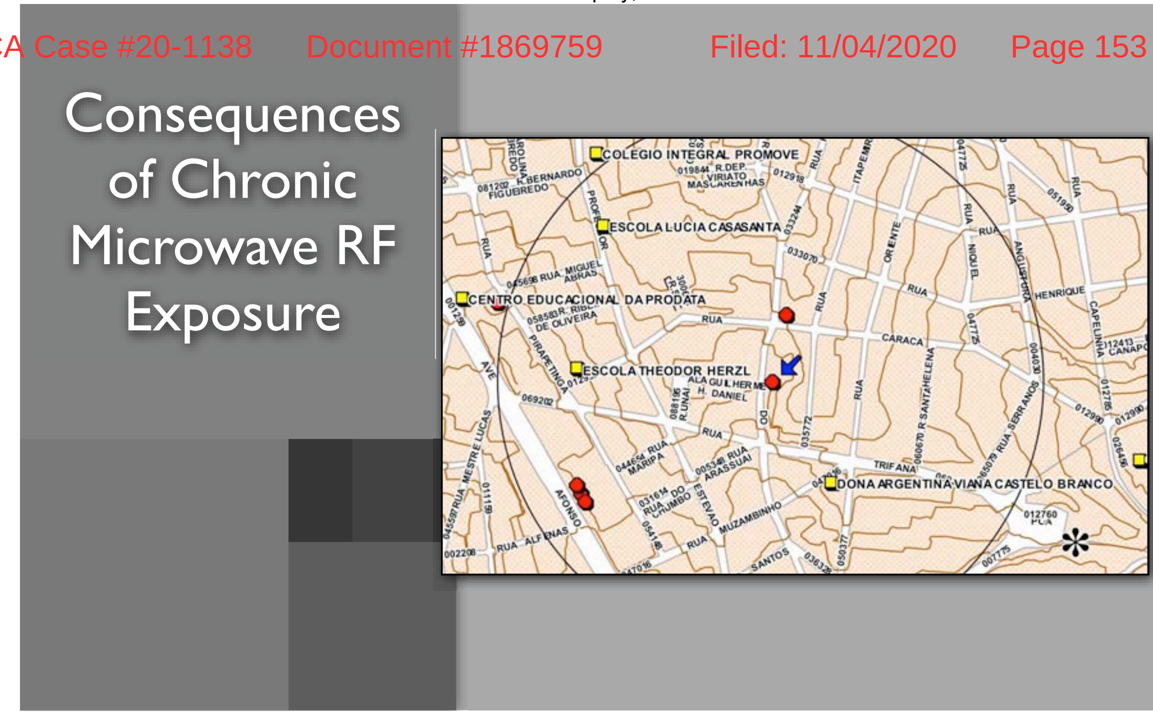
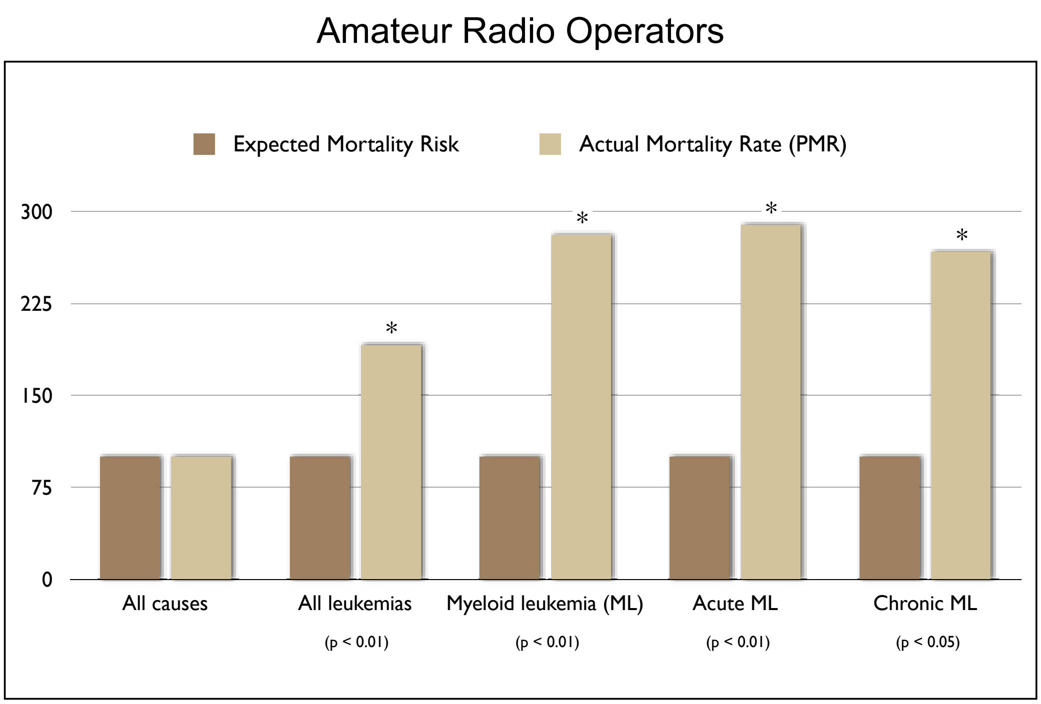


Fig. 2. Geographical location of BS Site BH 20 at 1373 Rua do Ouro Street, in the Serra neighborhood, Belo Horizonte municipality

Dode AC, Leao MM, Tejo Fde A et al. Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil. *Sci Total Environ* (2011); 409(19):3649-3665.

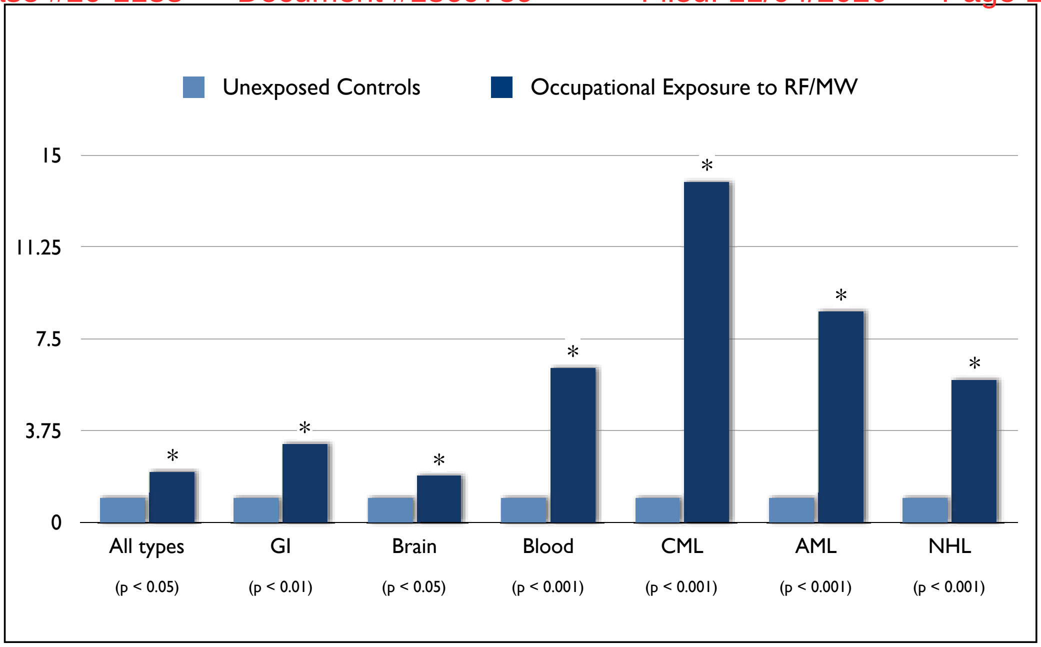


Analysis of leukemia deaths in male members of the American Radio Relay League resident in Washington and California, 1971-1983

Milham SJ. Silent keys: leukaemia mortality in amateur radio operators. *Lancet* (1985); 1(8432):812.

Cherry N. Evidence in support of the a priori hypothesis that Electromagnetic Radiation across the spectrum is a Ubiquitous Universal Genotoxic Carcinogen. (2002):1-52. http://www.neilcherry.com/documents.php

Polish Military (1971-1985)



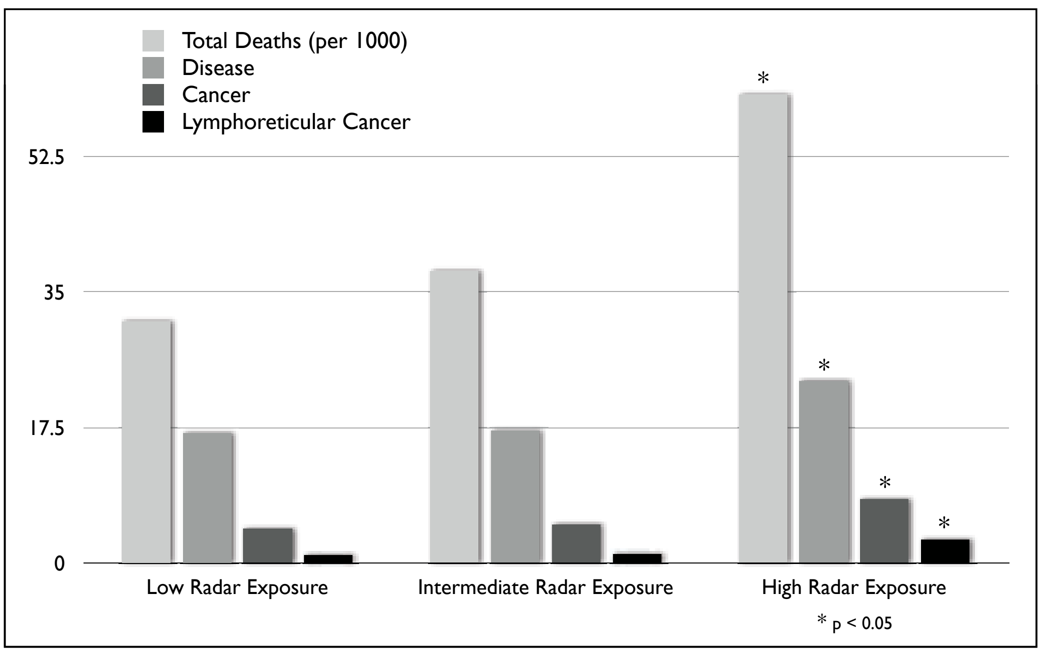
Polish military personnel with occupational exposure to radio and microwave frequency radiation.

Odds ratio of cancer incidence (1971-1985)

CML = chronic myelocytic leukemia
AML = acute myeloblastic leukemia
NHL = non-Hodgkin lymphoma

Szmigielski S. Cancer morbidity in subjects occupationally exposed to high frequency (radiofrequency and microwave) electromagnetic radiation. *Sci Total Environ* (1996); 180(1):9-17.

U.S. Navy Korean War Veterans (1950-1974)



Mortality in U.S. Navy Korean War Veterans (1950–1974) stratified by levels of occupational radar exposure.

Mortality 1950–1974. (Y axis = crude mortality per 1000) Stratified by level of radar exposure.

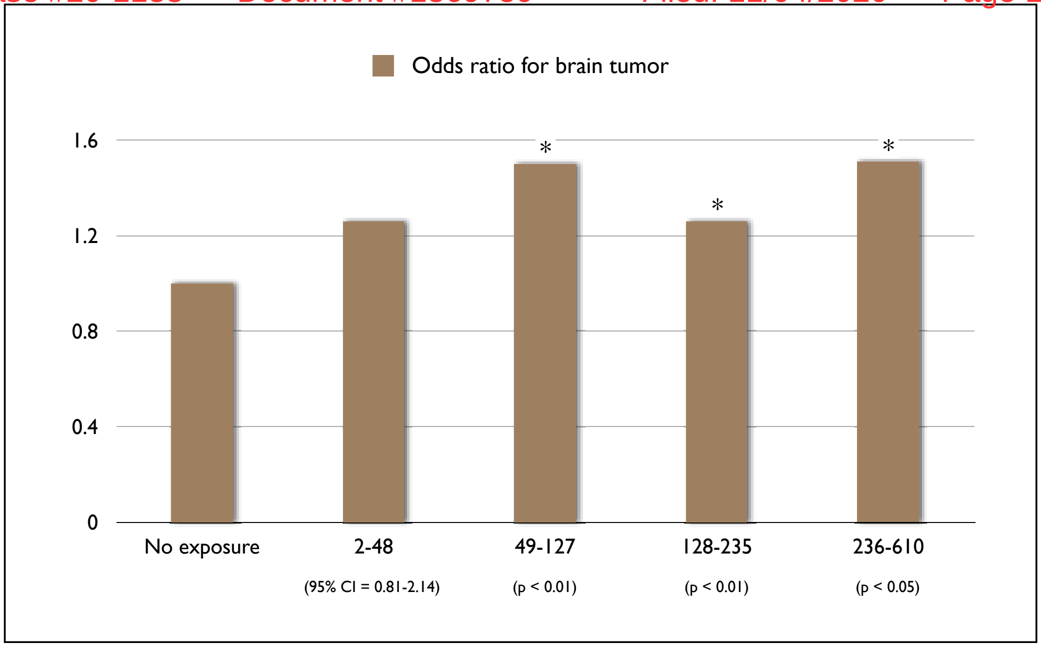
In the original paper, Robinette et al evaluated job exposure hazard levels of 6 categories of navy personnel and grouped them into two groups, low exposure and high exposure. The electronic technicians (ET) had a significantly lower hazard rating and lower levels of pathology than the other two job categories in the high risk group, so this classification diluted out the high exposure risk pool.

Dr. Cherry took Robinette et al's published data and divided the workers into three exposure levels. The above chart is the result of Dr. Cherry's analysis of the data set.

Robinette CD, Silverman C, Jablon S. Effects upon health of occupational exposure to microwave radiation (radar). *Am J Epidemiol* (1980); 112(1):39-53.

Cherry N. Health Effects in the vicinity of Radio/TV towers and mobile phone base stations. (2002): 1-40. http://www.neilcherry.com/documents.php

US Air Force (1970-1989)



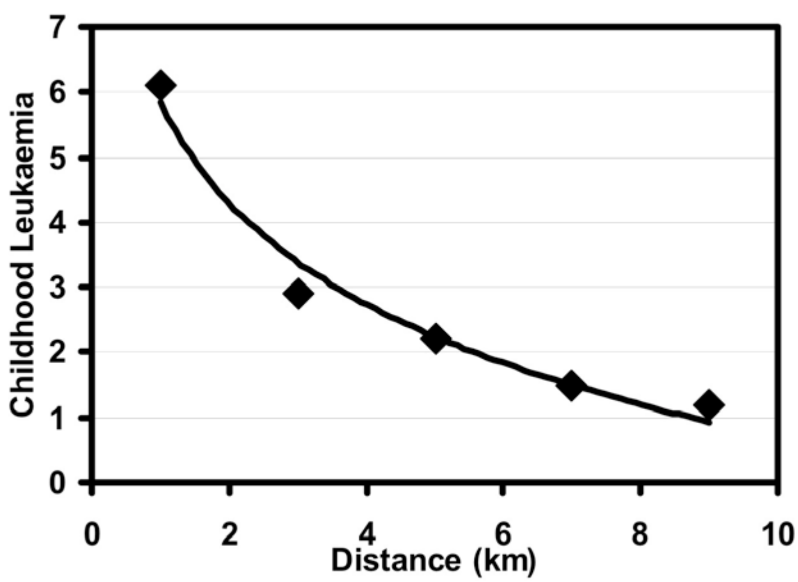
US Air Force Workers with occupational exposure to microwave RF (1970–1989)

Y axis: Odds ratio for brain tumor

X axis: Exposure intensity score x months exposed)

Grayson JK. Radiation exposure, socioeconomic status, and brain tumor risk in the US Air Force: a nested case-control study. *Am J Epidemiol* (1996); 143(5):480-486.

Vatican Radio Tower (1987-1999).



Cumulative childhood leukaemia near the Vatican Radio Transmitters in Rome, 1987–1999.

Multiple powerful transmitters on site.

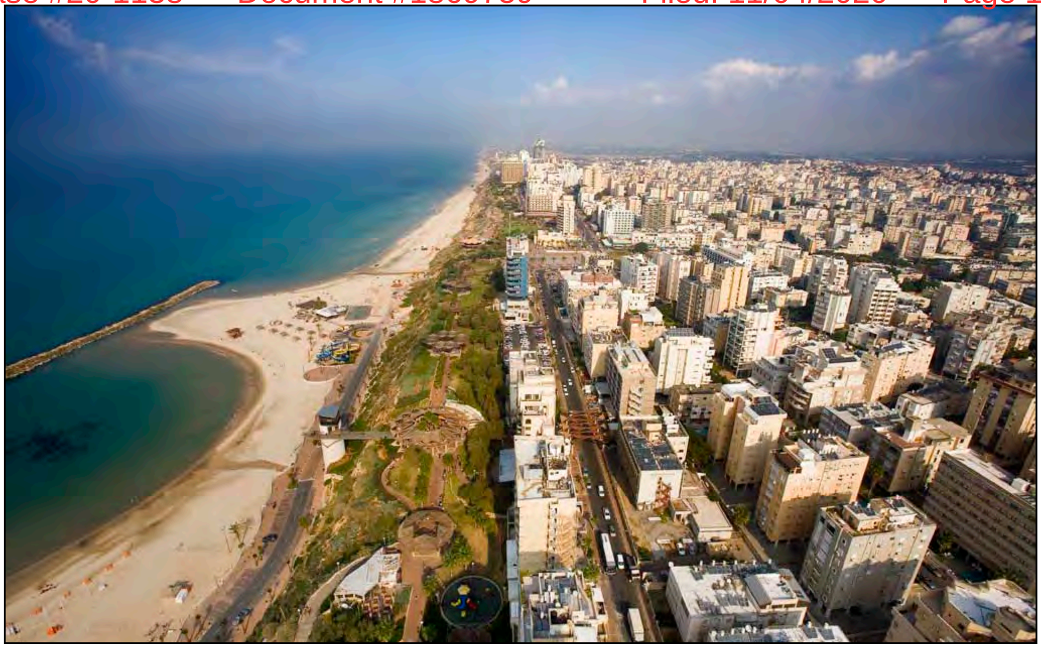
10 km radius around towers contains a population of >49,650 (1990 census).

exponential fitted trend line, R2=0.9756, **p = 0.002**

Cherry N. Health Effects in the vicinity of Radio/TV towers and mobile phone base stations. (2002): 1-40. http://www.neilcherry.com/documents.php

Michelozzi P, Capon A, Kirchmayer U et al. Adult and childhood leukemia near a high-power radio station in Rome, Italy. *Am J Epidemiol* (2002); 155(12):1096-1103.

Netanya, Israel (1997-1998)



New cell phone tower set up in city of Netanya, Israel, in July, 1996.

1500 watt, 850 MHz.

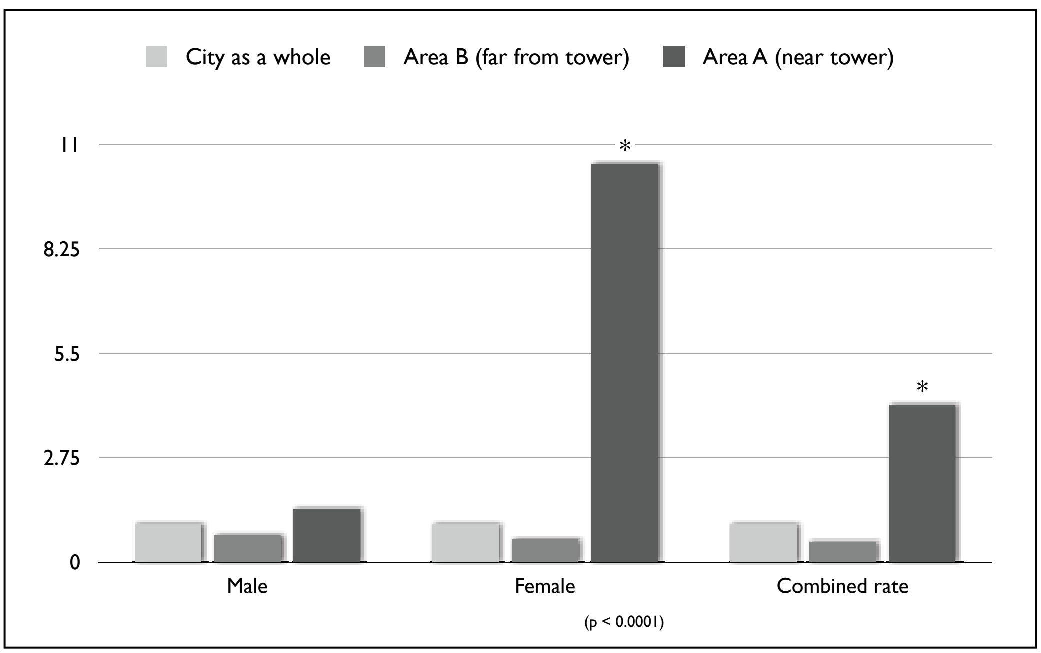
Power density in the whole exposed area was **far below 0.53 µw/cm2**.

This is <u>1000 times less</u> than the FCC Guidelines of 600 µW/cm² for 850 MHz exposure.

Comparison of cancer rates during the second year of exposure, in 677 long-term residents near the tower, compared to 1,222 matched controls living in another area of the city.

Wolf R, Wolf D. Increased Incidence of Cancer Near a Cell-Phone Transmitter Station. *International Journal of Cancer Prevention* (2004); 1(2):1-19.

Netanya, Israel - Relative Cancer Risk



Relative risk of cancer in residents near a new cell phone tower in Netanya, Israel, during the second year of exposure.

Overall risk of cancer in Area A was 4.15 times higher than in the town as a whole.

For men in area A, the cancer rate was 1.4 times higher.

For women in area A, the cancer rate was 10.5 times higher ($p < 0.0001$)

[the probability of this beeing a random finding is one hundredth of 1%

Wolf R, Wolf D. Increased Incidence of Cancer Near a Cell-Phone Transmitter Station. *International Journal of Cancer Prevention* (2004); 1(2):1-19.

Naila, Germany (1999-2004)

Town of ~ 1100 residents.

Cell tower installed in 1993.

Medical of 1000 residents reviewed for the years 1994–2004.

Comparison of cancer incidents in residents living within 400 meters of the cell phone tower,

compared to residents living farther away,

and compared to the death rates for the province as a whole.

Eger H, Hagen K, Lucas B, Vogel P, Voit H. The Influence of Being Physically Near to a Cell Phone Transmission Mast on the Incidence of Cancer. *Umwelt·Medizin·Gesell-schaft* (2004); 17(4):1-7.

Cancer Incidence in Naila (1999-2004)

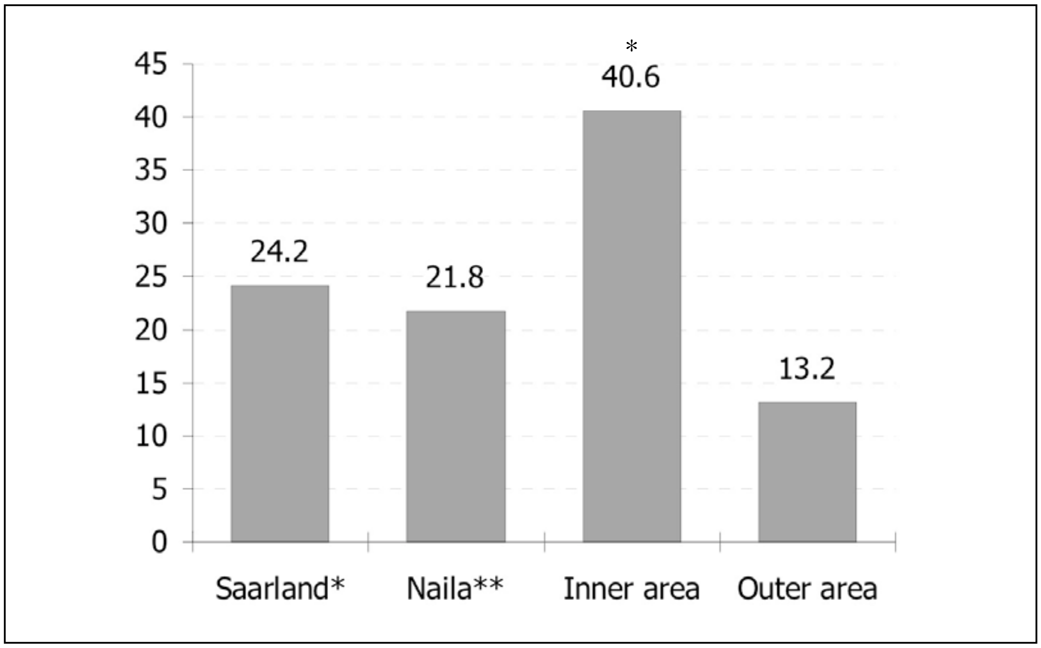


Fig. 3 : Number of new cancer cases 1999 to 2004, adjusted for age and gender, calculated for the 5,000 patient years

Y axis: Cancer incidence 1994 – 2004 (**new cases per 5000 patient years**).

* Saarland = predicted rate based on the cancer registry for the federal state of Saarland.

** Naila = incidence for the town as a whole.

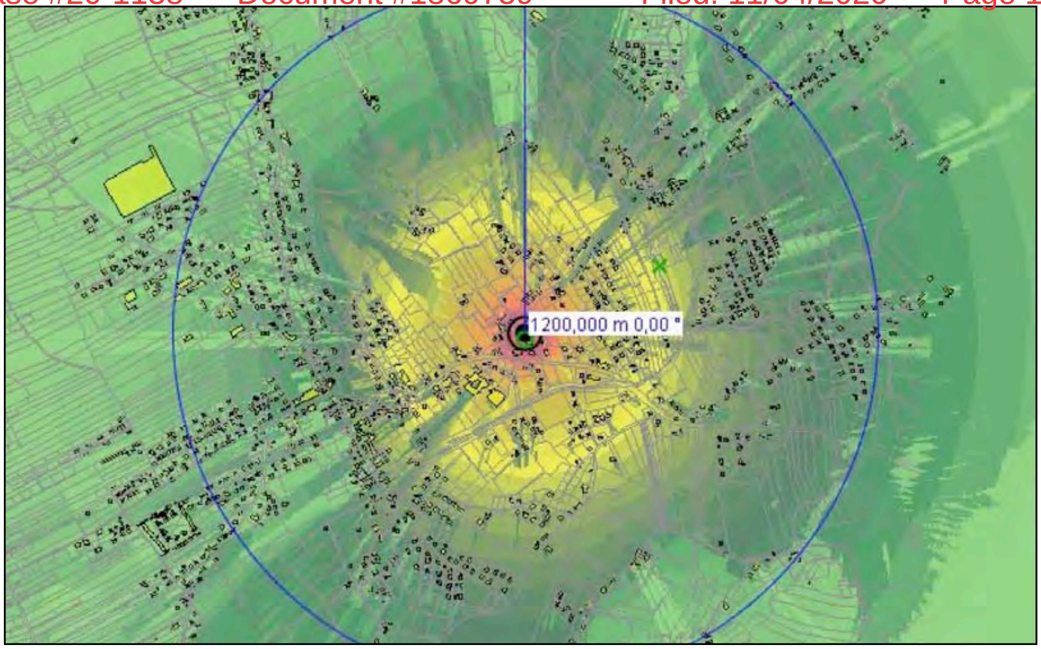
Inner area = residence within 400 meters of the tower.

Outer area = remainder of community.

In the inner area, the risk of cancer incidence was three times as high after five or more years of exposure.

In addition, the **patients that live within 400 metres tend to develop the cancers at a younger age**.

Hausmannstätten & Vasoldsberg, Austria (1984-1997)

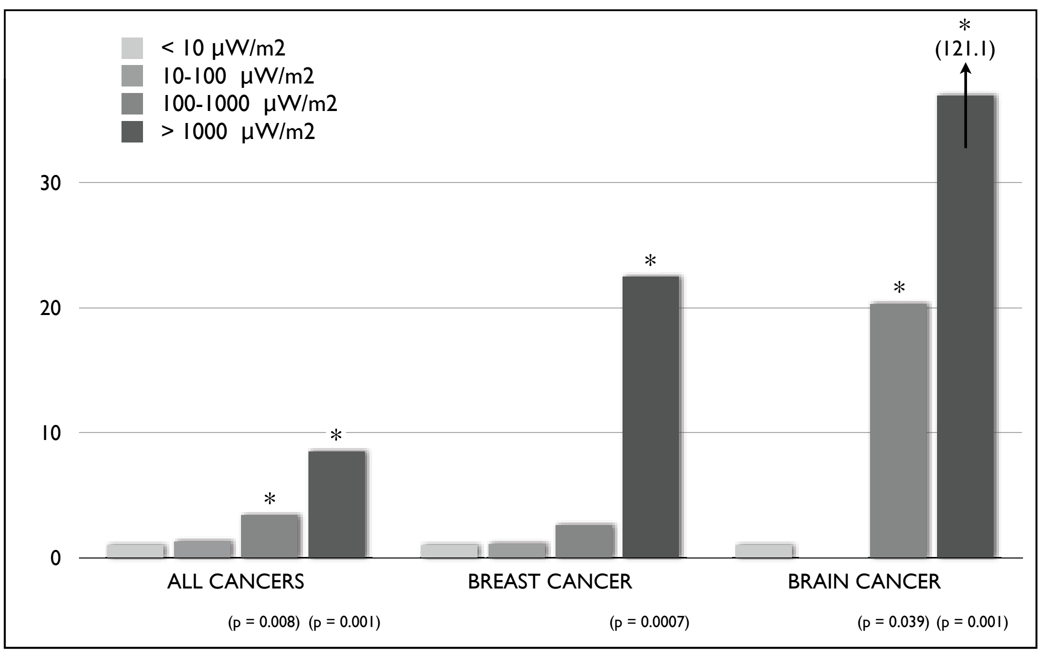


NMT 450 cell tower, operational from 1984–1997.

Case/control study of cancer patients living within 1200 meter radius of the tower.

Oberfeld G. Environmental Epidemiological Study of Cancer Incidence in the Municipalities of Hausmannstätten & Vasoldsberg (Austria). Provincial Government of Styria, Department 8B, Provincial Public Health Office, Graz, Austria (2008):1-10. *http://www.emf-health.com/PDFreports/Austrianstudy.pdf*

Hausmannstätten & Vasoldsberg, Austria (1984-1997)



Odds ratio of cancer incidence — stratified by exposure levels (exterior to dwelling) in μW/m² .

Note: **FCC thermal safety guidelines ~ 6,000,000 μW/m²**)

In the highest exposure category:

Breast cancer risk was 23 times higher,

Brain cancer risk was 121 times higher.

Oberfeld G. Environmental Epidemiological Study of Cancer Incidence in the Municipalities of Hausmannstätten & Vasoldsberg (Austria). Provincial Government of Styria, Department 8B, Provincial Public Health Office, Graz, Austria (2008):1-10. *http://www.emf-health.com/PDFreports/Austrianstudy.pdf*

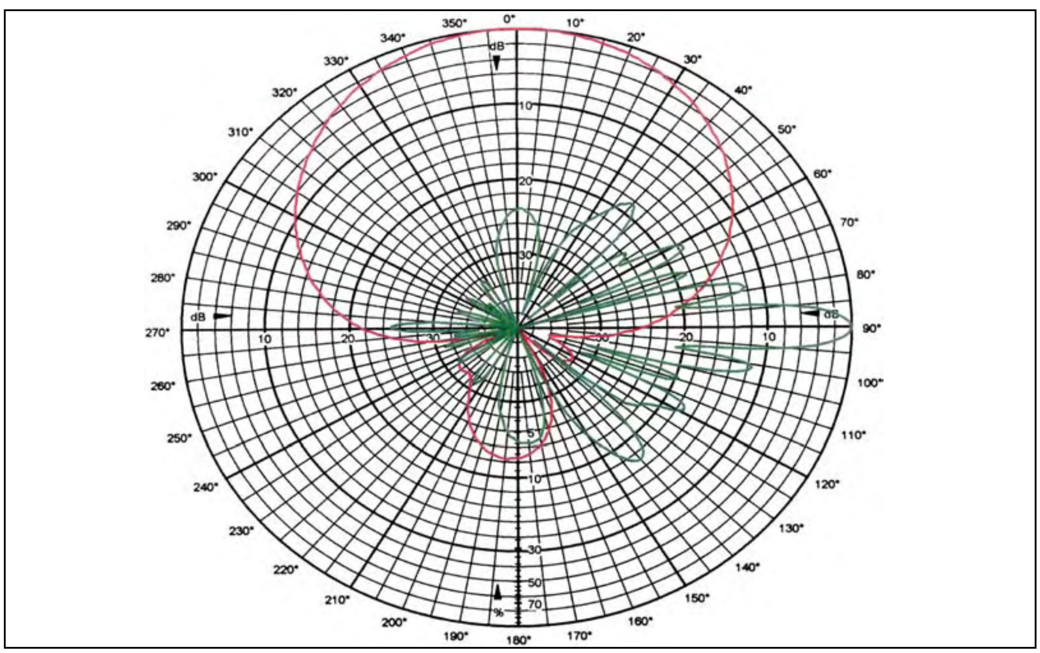
Belo Horizonte, Brazil (2011)

Belo Horizonte is the capital of Minas Gerais state in Brazil, population 2,258,096 in 2010.

Rated by the U.N. in 2007 as having the best quality of life in Latin America.

By 2006, 856 cell phone towers had been installed in the city.

Dode AC, Leao MM, Tejo Fde A et al. Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil. *Sci Total Environ* (2011); 409(19):3649-3665.



Environmental monitoring of RF power densities in the city was performed.

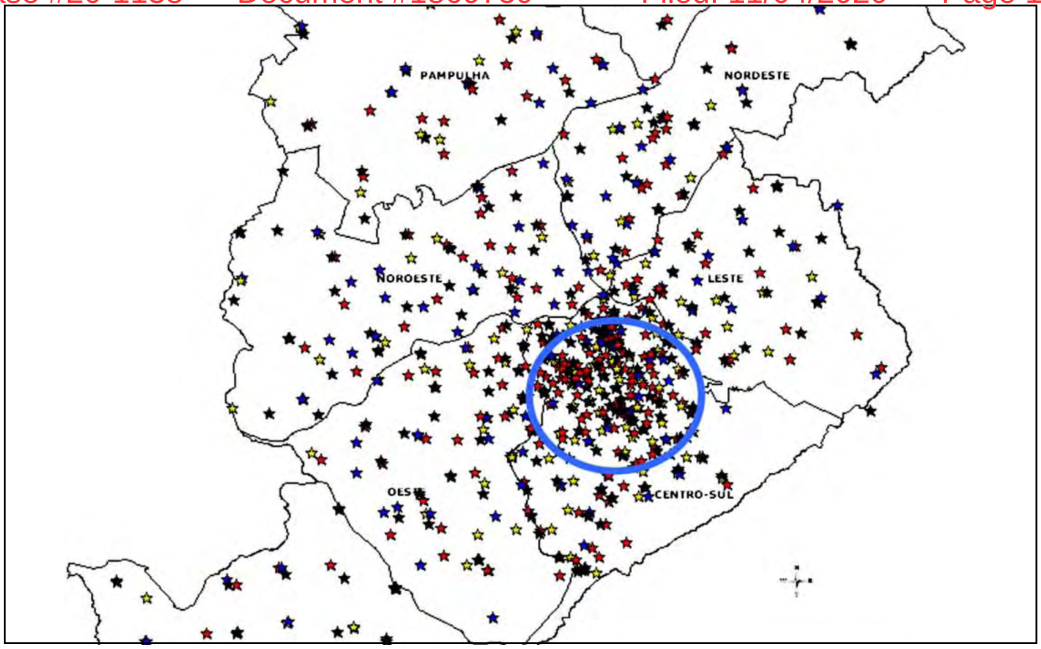
In 2003, the highest recorded power density in the city was 3.06 µW/cm2.

In 2008, the largest recorded power density was 40.78 µW/cm2, 13 times higher than in 2003.

40 µW/cm2 is 15 times less than the FCC Exposure Guidelines.

Fig. 3. Horizontal and vertical radiation patterns per sector of BS site BH 20

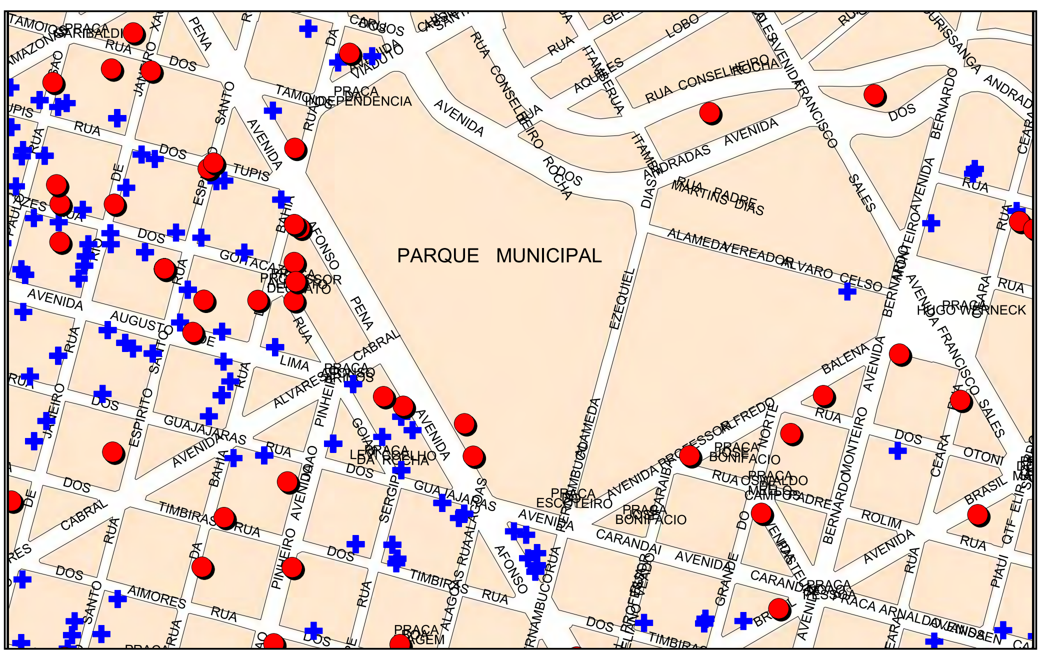
From: Dode AC, Leao MM, Tejo Fde A et al. Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil. *Sci Total Environ* (2011); 409(19):3649-3665.



The authors used the Telecommunications National Agency database to map the locations of the 856 cell phone towers that existed in the city as of December 2006.

Fig. 8. Installed BSs in the Belo Horizonte municipality until 2006. Total amount = 856.

Dode AC, Leao MM, Tejo Fde A et al. Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil. *Sci Total Environ* (2011); 409(19):3649-3665.



They then cross-referenced health department records of death by neoplasia
with census and demographic city population data
to **locate the residence** of all individuals who had died of cancer in the city between 1996 and 2006.

Fig. 10. Sample of geocoded deaths and BS locations in downtown Belo Horizonte City located in Central-Southern region.

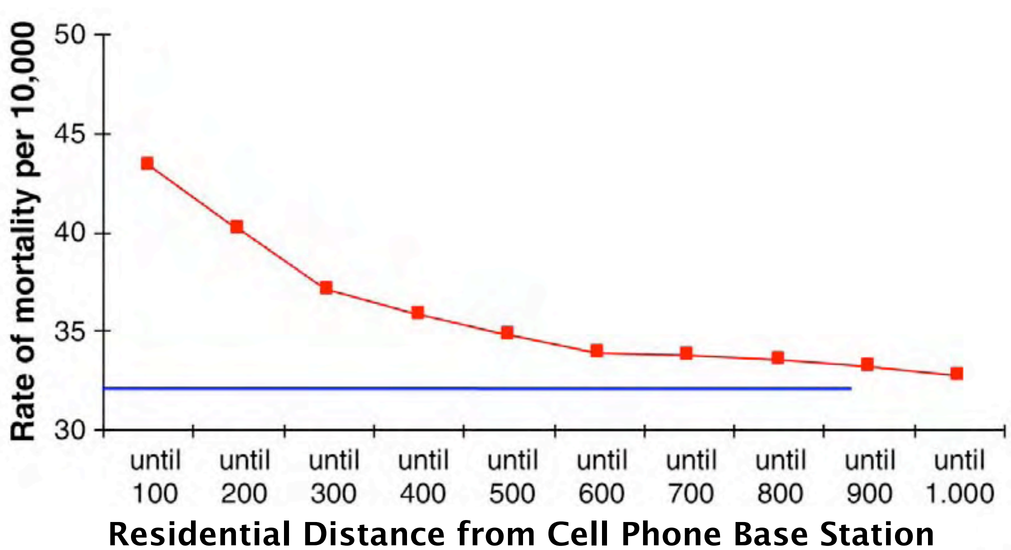
From: Dode AC, Leao MM, Tejo Fde A et al. Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil. *Sci Total Environ* (2011); 409(19):3649-3665.

Belo Horizonte, Brazil (2011)

This allowed them to calculate the distance between the deceased individuals' residences and the closest cell phone tower, in meters.

Dode AC, Leao MM, Tejo Fde A et al. Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil. *Sci Total Environ* (2011); 409(19):3649-3665.

Belo Horizonte, Brazil (2011)

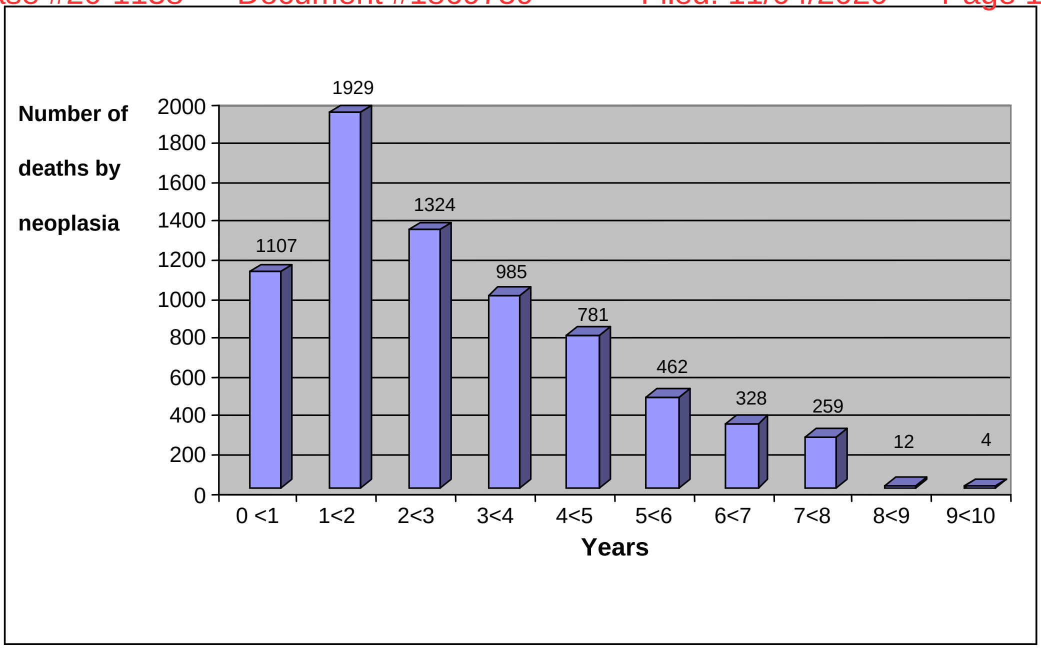


Analysis of this data showed that the cancer death rate was significantly elevated at proximities closer than 500 meters to cell phone towers.

Fig. 15. Rate of mortality by neoplasia, according to the distance from the BS in Belo Horizonte municipality, from 1996 to 2006, and the null hypothesis (blue line).

Dode AC, Leao MM, Tejo Fde A et al. Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil. *Sci Total Environ* (2011); 409(19):3649-3665.

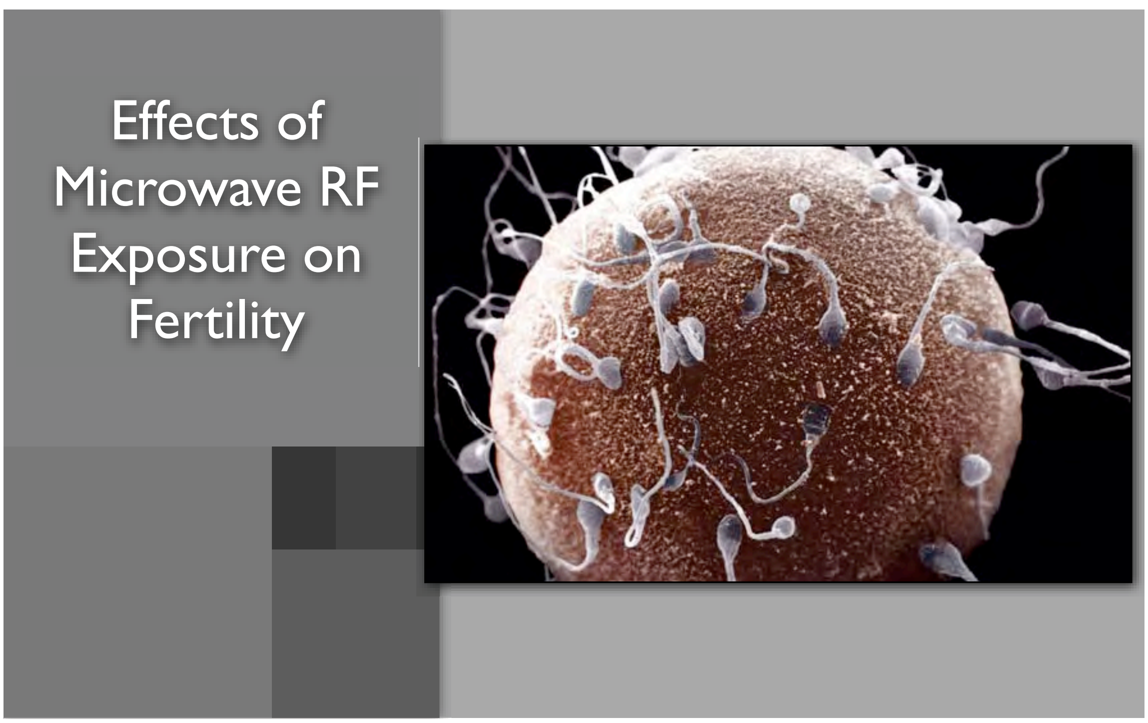
Belo Horizonte, Brazil (2011)



Death rates peaked during the second year of exposure.

Fig. 16. Distribution of the number of deaths by neoplasia versus duration of exposure since the date that the first antenna in each analyzed CT came into operation.

Dode AC, Leao MM, Tejo Fde A et al. Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil. *Sci Total Environ* (2011); 409(19):3649-3665.



Cell Towers - Cancer; Meta-Analysis, Long-Term Exposure To Microwave Radiation Provokes Cancer Growth: Evidences From Radars And Mobile Communication Systems. (Yakymenko et al); 2011

Exp Oncol 2011
33, 2, 62–70

Experimental ONCOLOGY

REVIEW

LONG-TERM EXPOSURE TO MICROWAVE RADIATION PROVOKES CANCER GROWTH: EVIDENCES FROM RADARS AND MOBILE COMMUNICATION SYSTEMS

I. Yakymenko[1,2]*, *E. Sidorik*[1], *S. Kyrylenko*[3], *V. Chekhun*[1]

[1]*R.E. Kavetsky Institute of Experimental Pathology, Oncology and Radiobiology of NAS of Ukraine, Vasylkivska str. 45, Kyiv 03022, Ukraine*
[2]*Bila Tserkva National Agrarian University, Soborna pl. 8/1, Bila Tserkva 09117, Ukraine*
[3]*Masaryk University, Kamenice 5, A6, Brno 625 00, Czech Republic*

In this review we discuss alarming epidemiological and experimental data on possible carcinogenic effects of long term exposure to low intensity microwave (MW) radiation. Recently, a number of reports revealed that under certain conditions the irradiation by low intensity MW can substantially induce cancer progression in humans and in animal models. The carcinogenic effect of MW irradiation is typically manifested after long term (up to 10 years and more) exposure. Nevertheless, even a year of operation of a powerful base transmitting station for mobile communication reportedly resulted in a dramatic increase of cancer incidence among population living nearby. In addition, model studies in rodents unveiled a significant increase in carcinogenesis after 17-24 months of MW exposure both in tumor-prone and intact animals. To that, such metabolic changes, as overproduction of reactive oxygen species, 8-hydroxi-2-deoxyguanosine formation, or ornithine decarboxylase activation under exposure to low intensity MW confirm a stress impact of this factor on living cells. We also address the issue of standards for assessment of biological effects of irradiation. It is now becoming increasingly evident that assessment of biological effects of non-ionizing radiation based on physical (thermal) approach used in recommendations of current regulatory bodies, including the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines, requires urgent reevaluation. We conclude that recent data strongly point to the need for re-elaboration of the current safety limits for non-ionizing radiation using recently obtained knowledge. We also emphasize that the everyday exposure of both occupational and general public to MW radiation should be regulated based on a precautionary principles which imply maximum restriction of excessive exposure.
Key Words: **non-ionizing radiation, radiofrequency, tumor, risk assessment, safety limits, precautionary principle.**

INTRODUCTION

Electromagnetic radiation (EMR) became one of the most significant and fastest growing environmental factors due to intensive development of communication technologies during the last decades. Currently, according to expert estimations, the level of electromagnetic radiation from artificial sources exceeds the level of natural electromagnetic fields by thousand folds. The active development of mobile communication technologies over the world will only raise this level further. In this connection the problem of possible adverse effects of anthropogenic EMR on human health and particularly strictest assessment of possible carcinogenic effects of EMR is extremely important.

In August 2007 an international working group of renowned scientists and public health experts released a report on electromagnetic fields (EMF) and human health [1]. It raised a serious concern about safety limits for public electromagnetic irradiation from power lines, cell phones, radars, and other sources of EMF exposure in daily life. The authors concluded that the existing public safety limits were inadequate to protect public health. Moreover, very recently a vast number of new extremely important studies in this field have been published. Importantly, nowadays the problem is discussed on highest political level over the world. It appears that the most sound political document in Europe is a European Parliament Resolution from April 2, 2009 (*www.europarl.europa.eu*), where the direct appeals to activate the research and business strategy for effective solving of the problem over the member states were indicated.

In this review we would like to analyze the results of studies on specific biological effects of microwaves (MW), both epidemiological and experimental that deal with cancer promotion by long term low intensity microwave irradiation of human/animal beings. We will concentrate on unequivocal studies and will not analyze ambiguous data. For additional analysis of microwave risks we can recommend recently published reviews [2–10].

MICROWAVES OF RADARS AND MOBILE COMMUNICATION SYSTEMS

Microwaves are non-ionizing electromagnetic radiation. That means MW is a type of electromagnetic radiation which does not carry enough energy

Received: March 21, 2011.
*Correspondence: Fax: +380456351288;
E-mail: yakymenko@btsau.net.ua

Abbreviations used: 8-OH-dG — 8-hydroxi-2-deoxyguanosine; EGF — epidermal growth factor; EMF — electromagnetic field; EMR — electromagnetic radiation; ERK — extracellular-signal-regulated kinase; GSM — Global System for Mobile communication; ICNIRP — International Commission on Non-Ionizing Radiation Protection; MW — microwaves; NHL — Non-Hodgkin lymphoma; ODC — ornithine decarboxylase; OER — observed expected ratio; OR — odds ratio; ROS — reactive oxygen species; SAR — specific absorption rate; SIR — standardized incidence ratio; SMR — standardized mortality ratio; WHO — the World Health Organization.

for ionization of atoms and molecules under normal conditions and unlike the ionizing radiation this kind of radiation generally has not enough energy for breaking the intermolecular bonds or for breakaway of electrons from atoms or molecules. MW comprise a part of radiofrequency range. Radiofrequency radiation (RF) refers to electromagnetic waves with a rate of oscillation of electromagnetic fields in the range from 30 kHz to 300 GHz. As any other electromagnetic waves, the radio waves are pulses of electric and magnetic fields. These fields regenerate each other as they move through the space at the speed of light. MW have frequencies from 300 MHz to 300 GHz. As MW have the highest frequency among other RF, it carries the highest energy and produce most thermal effect upon interaction with the matter.

The main sources of radiofrequency radiation during a long period in previous century were broadcasting systems. In some cases, for example, in military and aviation the most powerful local sources of radiofrequency radiation were and still are radars (RAdio Detection And Ranging). However, the situation changed dramatically for general population during recent decades; and currently the most prevailing sources of RF in nearest human environment are mobile communication systems. It is important that both radars and systems for mobile communication use the same microwave part of radiofrequency spectrum.

Radar systems are type of powerful sources of pulsed MW which generally effect only certain groups of military or service staff or population living nearby. Radars are detection systems which use MW to determine both moving and fixed objects like aircraft, ships, missiles, etc. Depending on the tasks they use different frequencies of MW, from 1GHz to 12 GHz.

Mobile communication systems are undoubtedly the most source of MW in human environment over the world nowadays. Starting from the first commercial mobile phone networks in Japan, Europe and USA since 1979–1983 the number of active users of mobile telephony increased globally to over five billion. In developed countries the number of cellular phone users today is over the point of saturation. It means that many people use more than one cell phone. The initial age of youngest users of cell phone is estimated as three years old [5].

Mobile communication technology utilizes MW for connection of cell phones and base transmitting stations. Phone refers to as mobile because it is free from wire connection and it refers to as cellular/cell because technology utilizes cellular network principle. All area is covered by many base transmitting stations, each station operates in one cell (part of area) and cell phone automatically changes the station when moves from one cell to another. In GSM (Global System for Mobile communication) standard, which covers about 80% of all services over the world the frequencies of electromagnetic waves used are about 850; 900; 1850; or 1900 MHz, which belongs to the microwave range. The useful information (sounds or images) is transferred by modulation of electromagnetic wave frequency. In GSM standard TDMA (Time Division Multiple Access) principle is realized. This means a part-time access of each consumer to the logical channel with frequency of channel rotation about 217 Hz. Thus, both base transmitting stations and cell phones emit MW modulated according to the digital standard.

SAFETY LIMITS FOR MICROWAVE RADIATION

The main international recommendations on safety levels of non-ionizing electromagnetic radiation is *Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)* of International Commission on Non-Ionizing Radiation Protection [11]. The document gives recommended safety limits in all ranges of EMR both for occupational and general public exposure. "Basis for limitation exposure" is dramatically important for understanding the imperfection of this document. Accordingly, the document directly states that "Induction of cancer from long-term EMF exposure was not considered to be established, and so these guidelines are based on short-term, immediate health effects such as stimulation of peripheral nerves and muscles, shocks and burns caused by touching conducting objects, and elevated tissue temperatures resulting from absorption of energy during exposure to EMF." However, the basic assumption of that is questioned nowadays by numerous data sources.

According to that document a few parameters of EMR energy are recommended to be restricted. Among them the two parameters are used the most often: 1) Specific Absorption Rate (SAR) in W/kg, which indicates the EMR energy absorbed per mass unit of human tissue per second; and 2) power density or intensity of incident radiation in W/m^2 (or μW/ cm^2) which indicates the amount of electromagnetic energy which falls on a unit of surface (under the right angle) per second. SAR safety limit for general public exposure indicated in Guidelines as 2 W/kg (for head and trunk) for the microwave range. To that, this limit is accepted by industry as mandatory for every commercial cell phone over the world, and real value of SAR of each cell phone model must be indicated in technical specification of the model. Unfortunately, SAR is rather sophisticated index for measurement. Moreover, only models of adult human head are currently used by industry for calculation of SAR, while real SAR values depend on a geometry and structure of tissues and, for example, was shown to be much higher for a child head than for the adult one [12–14].

Power density, or intensity of radiation, is much more direct and simple index as compared to SAR, although it does not estimate the specificity of interaction of EMR and the matter. Occupational exposure limits in microwave range according to ICNIRP are 10–50 W/ m^2. Public exposure limits for microwaves according to ICNIRP recommendation were set to 2–10 W/m^2 (or 200–1000 μW/cm^2) depending on fre-

quency. For example, for GSM–900 MHz standard ICNIRP safety limit will be calculated as 450 μW/cm² [11].

It is important to note that ICNIRP recommendations have no legal validity, as it is only a recommendation. Each country has their own national legislation in the field of electromagnetic safety, and national limits are rather different in different countries. Some countries such as the USA and Germany conformed national EMR limits to ICNIRP recommendation. Other countries have much tougher national limits as compared with ICNIRP guidelines. For example, for GSM-900 MHz standard MW safety limits are: in Italy, Russia and China — 10 μW/cm², in Switzerland — 4 μW/cm², in Ukraine — 2.5 μW/cm² [1]. As we can see, some countries, including Ukraine, have extremely strict national safety limits. Such national positions are explained first of all by long-term national research traditions in a field of electromagnetic biology, and on experience in studying the non-thermal biological effects of this kind of radiation. On the other hand, some countries like Switzerland follow a strict precautionary principle (Better protect than sorry).

RADAR RADIATION AND CANCER PROMOTION

Substantial military and occupational data indicate a significant effect of pulse microwaves on cancer development and other pathological conditions in human. Accordingly, a statistically significant increase in immature red blood cells among workers exposed to a radar was reported [15]. In addition, radar-exposed workers had significantly lower levels of leukocytes and thrombocytes than workers distant from MW sources.

Among Polish soldiers (128 thousand personnel subjects aged from 20 to 59 years), soldiers of 20–29 years old exposed to radar microwaves during 1970–1979 had cancer incidence rates 5.5 folds higher than non-exposed soldiers [16]. The greatest rise of cancer cases was detected in blood-forming organs and lymphatic tissues: by 13.9 folds for chronic myelocytic leukemia and 8.6 folds for myeloblastic leukemia. The level of mortality among all exposed personnel was significantly higher than in unexposed: for colorectal cancer (observed-expected ratio, OER 3.2; 95 %), for cancer of esophagus and stomach (OER 3.2; 95 %), cancer of blood-forming system and lymphatic tissues (OER 6.3; 95 %) [17].

Almost two times more cases of cancer were indicated in the high-exposed American naval personnel served during the Korean War (1950–1954) as compared with the low-exposed subjects among 40 thousands of personnel [18]. Death rates for aviation electronic technicians, the group with the highest exposure rate, were significantly higher than those for the other personnel during the following years up to 1974 [15].

A very substantial increase in cancer incidence was also detected in commercial airline pilots. Thus, the standardized incidence ratio (SIR) for malignant melanoma cases was 10.2; 95.5 % for pilots of commercial airlines in Iceland [19]. Significantly increased risks of acute myeloid leukemia (SIR 5.1), skin cancer, excluding melanoma (SIR 3.0) and total cancer (SIR 1.2) were observed also among Danish male jet pilots [20]. These data have been explained as a result of excess cosmic ionizing radiation or even excessive sun radiation during a leisure time. However, analysis of brain cancers among US Air Force personnel has revealed that non-ionizing radiation and particularly MW had significant effect on cancer development (odds ratio, OR 1.38; 95%), whereas ionizing radiation had negative association with cancer cases (OR 0.58; 95 %) [21]. To that, standardizing mortality ratio (SMR) for brain tumors was 2.1; 95 % among German male cockpit crew members (6,017 people) [22]. Cancer risk was significantly raised (risk ratio 2.2; 95%) among cockpit crew members employed for 30 years as compared to those employed for less than 10 years. In addition, Non-Hodgkin's lymphoma (NHL) was also increased (SMR 4.2; 95%) among male cabin crew members (20,757 people). Importantly, any increase in cancers associated with ionizing (cosmic) radiation was not detected in this cohort study.

In another report, six incident cases of testicular cancer occurred within a cohort of 340 police officers between 1979 and 1991 in Seattle, Washington, observed/expected ratio was 6.9; $p<0.001$ [23]. Occupational use of hand-held radar was the only shared risk factor among all six officers, and all had a routine habit of keeping the radar gun directly in close proximity to their testicles. Similarly, in Ontario, Canada risk assessment among police officers exposed to radar devices for speed measurement (1,596 females and 20,601 males) revealed an increased risk among men for testicular cancer (SIR 1.3) and for melanoma (SIR 1.45; 95 %) [24].

In another study, eighty seven persons working with radars (and 150 matched control) were divided into risk groups according to frequencies of MW (200 KHz to 26 GHz) and power density (8 μW/cm² to 300 μW/cm²) [15]. Three specific radiation cataracts in persons working with extremely high MW exposure were identified. Lens changes were associated with level of exposure in different risk groups.

Other occupational studies revealed the highest risk ratio (2.6) for acute myelogenous leukemia in radio and radar operators among all occupational groups studied [25]. In addition, excessive risk for breast cancer was detected (SIR 1.5) among Norwegian female radio and telegraph operators (2,619 women) with potential exposure to radio frequency (405 kHz — 25 MHz) [26].

RADIATION FROM MOBILE COMMUNICATION SYSTEMS AND CANCER PROMOTION

Cell phones. A significant increase of risk of particular brain tumors in long-term (10 years or more) users of cell phones and cordless phones has been detected in series of epidemiological studies of Swedish oncologist Prof. L. Hardell with colleagues [27–33].

It is important that for a short-term use of cell phones similar effects were absent or less evident [4].

The risk of development of high-grade glioma has increased in more than 3 times (OR 3.1; 95 %) for bilateral users of cell phones and in more than 5 times (OR 5.4; 95%) for ipsilateral users after 10 years of using [34].

The risk of development of acoustic neuroma for bilateral users of cell phones was OR 2.9; 95% and OR 3.5; 95 % for ipsilateral users after 10 years of using [29].

Notably, the highest risk of brain tumors has been detected in the youngest users of cell phones (20–29-yr) among all analyzed age groups (20–80 years old), with OR 5.91; 95% for ipsilateral use of cell phones. The highest risk was associated with more than 5-year using period in the 20–29-yr age group for analog cell phones (OR 8.17; 95%) [28].

International multiyear Interphone project conducted under the management of the World Health Organization and substantially supported by industry, was an interview-based case-control study with 2708 glioma and 2409 meningioma cases and matched controls, conducted in 13 countries using a common protocol [35]. The results of study were rather controversial. For example, authors were forced to declare "a reduced odds ratio related to ever having been a regular mobile phone users was seen for glioma (OR 0.81; 95 %) and meningioma (OR 0.79; 95 %), possibly reflecting participation bias or other methodological limitations." However, significantly increased risks of tumors development in "heavy" users of cell phones (with more than 1640 hours of using during less than four years) have been revealed in this study: for meningioma OR 4.8; 95 %, for glioma OR 3.77; 95% as compared with the matched controls [35]. One thousand and six hundred forty hours per four years means about one hour per day of a cell phone use. In this connection we can point to our data [36] that indicates amount of time which Ukrainian students (like students in other countries?) spend talking via cell phones every day. Our findings indicated that more than a half of them spend over one hour per day, and more than a quarter of them spend over two hours per day talking via cell phones every day.

Parotid gland, like a human brain, is another potential target for cell phone MW radiation during cell phone talks without hands-free devices. Thus, a study done by an Israeli team has indicated an association between a cell phone use and parotid gland tumors [37]. This study comprised 402 benign and 58 malignant cases of parotid gland tumors diagnosed in Israelis at age over 18 years in 2001–2003. The risk of parotid malignant tumors in intensive users of cell phones (for users with more than 5,479 hours of a use during less than five years) were OR 2.26; 95%. Recently new data have been published that totally a 4-fold increase of parotid malignant tumors in Israel during 1970–2006 took place, whereas other salivary glands tumors had been almost on a stable level during that period of time [38]. Previously, a Finnish study has revealed the OR 5.0; 95% for salivary gland cancer among all Finland digital cell phone subscribers compared with control population after one-two years of a cell phone use [39].

The odds ratio for Non-Hodgkin's lymphoma of T-cell, cutaneous and leukemia types has been found for analogue-cell-phone users as 3.4; 95%; for digital-phone users 6.1; 95 %; and for cordless-phone users 5.5; 95% by L. Hardell group [40]. An American study indicated OR 1.6; 95 % for NHL in users of cell phones with a period of use over eight years [41].

Uveal melanoma (in analysis of 118 cases with uveal melanoma and 475 controls in Germany) has been indicated to have odds ratio 4.2; 95% for people probable/certain exposed to cell phone radiation [42].

Testicular cancer (seminoma) risk had odds ratio 1.8; 95% for men keeping a cell phone during "stand by" in ipsilateral trousers pocket [43]. The results have been based on 542 cases of seminoma in Sweden.

Base transmitting stations. During the last decades more than one and half million base transmitting stations for mobile communication have been installed over the world. However, the World Health Organization suggested a priority to study effects mainly of cell phones, while discouraging studies on the effects of transmitting stations (with an exception of years 2003–2006 when WHO recommended studies of possible effects of radiation of transmitting stations as well) [44]. This is probably the main reason why only a few publications on this particular problem can be found to date [45–49].

The comparison of cancer cases among people living up to 400 m from base transmitting station and people living further than 400 m from station during 1994–2004 was carried out in Germany [48]. A total increase of cancer cases among people living nearby to transmitting station over the control population was 1.26 times during the first five-year period (1994–1998), and 3.11 times during the second five-year period (1999–2004) of operation of the station. Particularly, in the second period the increase of cancer cases was statistically significant both as compared with the population from more distant area and with the expected background incidence.

Population (n=622) living in the area nearby (up to 350 m) the cell phone base transmitting station (850 MHz, 1500 watt of full power) during one year of operation and matched individuals (n=1222) from other area have been compared In Israel [47]. There were 4.15 times more cases of cancer in transmitted station area than in the rest of a city. Relative cancer rates for females were 10.5 for close to station area, 0.6 for control area and 1 for the whole town. Cancer incidence of women in close to base station area was significantly higher ($p<0.0001$) as compared with the control area and the whole city. Keeping in mind that very significant increase in a number of cancer cases took place during only one year period, the authors of the study suggested that MW could provoke latent

cases of cancer in inhabitants of the area nearby transmitting station.

French and Spanish researchers also revealed that inhabitants living near base station for mobile communication (up to 300 m) developed significantly higher rates of many subjective symptoms of health like headache, fatigue, sleep disorder, depression as compared with the matched control from distant area [49, 50].

RODENT MODEL OF CANCER PROMOTION BY MICROWAVES

A highly representative research has been carried out at the University of Washington, Seattle commissioned by US Air Force [51]. The experimental rats (100 animals) were exposed during 24 months at 21.5 hours per day to 2,450-MHz pulsed microwaves at 800 pps with a 10 µs pulse width. The pulsed microwaves were square-wave modulated at 8 Hz. An average SAR was 0.4 W/kg for a 200-g rat. It was a model of long-term irradiation of Air Force pilots to pulsed microwaves of radar systems. Totally 155 indexes of metabolisms were checked out during the study. As a result, the most expressive effect of long-term MW irradiation of animals was a dramatic increase in a level of cancer cases. In total, 3.6 folds more cancer cases were detected in irradiated animals than in matched control. Lymphoma cases were diagnosed in the irradiated animals 4.5 times more often than in the control group. In addition, benign tumors of adrenal were detected seven folds more often in the irradiated animals than in the control.

In the next study under US Air Force contract, 200 female C3H/HeJ mice were exposed for 21 months (22 h/day, 7 days/week) to a horizontally polarized 435 MHz pulse-wave (1.0 ps pulse width, 1.0 kHz pulse rate) RF radiation environment with an incident power density of 1.0 mW/cm^2 (SAR 0.32 W/kg), while 200 mice were sham-exposed [52]. Although under the conditions of this study, an exposure of mice prone to mammary tumors did not affect the incidence of mammary tumors, when compared with the controls, some other tumor cases increased markedly. For example, bilateral cases of ovary epithelial stromal tumor raised by five folds; multiple cases of hepatocellular carcinoma, raised 3 folds, and adrenal gland tumor cases (total) raised 1.63 folds.

In the third published study of this series [53] the same prone-mammary tumor mice were irradiated during 20 months to continuous wave 2450 MHz MW radiation with SAR from 0.3 to 1 W/kg (20 h/day, 7 days/week). A hundred mice were exposed, while 100 mice were used as sham-exposed. As a result, the exposed mice had higher level of mammary tumors (1.27 folds), and higher total level of all types of tumor (1.38 folds) as compared with sham-exposed; the difference between groups was statistically insignificant. Meanwhile, multiple mammary tumor cases occurred in exposed mice twice more frequently than in sham exposed.

In other study mice with high incidence of spontaneous breast cancer and mice treated with 3,4-benzopyrene (BP) were irradiated to continuous wave 2,450 MHz microwaves in an anechoic chamber at 5 or 15 mW/cm^2 (2 hours daily, 6 sessions per week, 3 months) [54]. Irradiation with MW at either 5 or 15 mW/cm^2 resulted in acceleration of development of BP-induced skin cancer. Microwaves-exposed mice with high incidence of spontaneous breast cancer developed breast tumors earlier than control. Authors indicated that the promotion of cancer development and lowering of natural antineoplastic resistance was similar in mice exposed to MW at 5 mW/cm^2 and chronically stressed by confinement, but level of cancer cases in animals exposed to 15 mW/cm^2 was significantly higher as compared to chronically stressed by confinement control.

And in well-known study of M. Ripacholi *et al.* (1997) transgenic mice moderately predisposed to develop lymphoma spontaneously have been used for exposure to MW of 900 MHz, with pulse repetition frequency of 217 Hz, incident power densities of 2.6–13 W/m^2, and average SAR of 0.13–1.4 W/kg [55]. One group of mice (101 females) has been exposed for two 30-min periods per day during 18 months. Another group of mice (100 females) has been a sham-exposed control. Lymphoma risk was significantly higher, more than twice, in the exposed mice than in the matched control (OR 2.4; 95 %). In particular, follicular lymphoma was the major contributor to the increased tumor incidence.

MICROWAVES AND CELL METABOLISM

Free radical species, including reactive oxygen species (ROS), is an intrinsic feature of cell metabolism [56–58]. But disturbance of redox balance, uncontrolled activation of free radical processes, overproduction of ROS and/or suppression of antioxidant defense in cell often are the important signals of some hazardous changes in cell metabolism [59, 60]. That is why data indicated oxidative effect of some factor is extremely important in risk-assessment research.

A significant increase of ROS and nitrogen oxide generation in cells under non-thermal intensities of MW has been detected both *in vivo* [61–67] and *in vitro* [68–72]. Possibilities of mitochondrial and membrane NADH oxidase dependent ways of ROS generation in exposed cells have been suggested [71, 72]. Accordingly, it was found that the first step in MW (875 MHz, 0.07 mW/cm^2) interaction with model cells (Rat1 and HeLa) was mediated in the plasma membrane by NADH oxidase, which can rapidly (during the minutes) generate ROS [72]. ROS directly stimulate matrix metalloproteinases and allow them to cleave and release heparin-binding epidermal growth factor (EGF). This secreted factor activates the EGF receptor, which in turn activates the extracellular-signal-regulated kinase (ERK) cascade and thereby induces transcription and other cellular pathways. On the other hand, on the model of purified human

spermatozoa exposed to MW (1.8 GHz, SAR from 0.4 W/kg to 27.5 W/kg) a significant overproduction of ROS in mitochondria was detected, along with a significant reduction in motility and vitality of spermatozoa [71]. All observed effects were significantly correlated with SAR levels, suggesting that significant effects of MW exposure occurred under non-thermal levels of MW.

Therefore, MW can induce cellular oxidative stress, which in turn can cause cancer stimulation [57, 59]. To that, it is known nowadays that in addition to damage via oxidative stress, ROS in cells can play a role of a secondary messenger for certain intracellular signaling cascades which can induce oncogenic transformation [60].

DNA damage in cells exposed to low-intensive microwaves both *in vivo* and *in vitro* was demonstrated during the last years in more than 50 independent studies [73]. The most often method used for detection of DNA damage after the MW exposure was alkaline Comet Assay. A statistically significant increase of both single strand and/or double strand breaks of DNA has been detected in humans [74, 75], animal models [76–79] and cell cultures [76, 80–83] exposed to low intensity microwaves.

Recently, an oxygen damage of DNA in human spermatozoa through formation of 8-hydroxi-2-deoxyguanosine (8-OH-dG) under non-thermal microwaves irradiation *in vitro* has been demonstrated [71].

Consequently, as DNA mutation is a critical step in carcinogenesis and increased level of 8-OH-dG takes place in many tumors [60], the possibility of MW to initiate oxidative damage of DNA is extremely dangerous signal for risk-assessment studies.

Ornithine decarboxylase (ODC) significantly changes its activity under conditions of non-thermal microwave exposure [84–88]. It was one of the first markers of carcinogenesis revealed to be activated under the low intensity microwaves exposure. ODC is involved in processes of cell growth and differentiation, and its activity is raised in tumor cells. Although overexpression of ODC is not sufficient for transformation of normal cells into tumorigenic ones, an increased activity of the enzyme was shown to promote the development of tumors from pre-tumor cells [89].

DISCUSSION AND CONCLUSIONS

In this review we presented evidences for carcinogenic effects of low intensity microwaves. Both epidemiological and experimental data led us to a conclusion that at least under certain conditions the exposure to long term low intensity MW can lead to tumorigenesis. Supporting evidences come from statistically significant epidemiological data based either on long-term analysis, e.g., on mortality of US Navy personnel in 20 years after expose during the Korean War [15], or on relatively short, one year exposure, e.g., by base transmitting station for mobile communication in Israel [47]. In the latter case we fully agree with the authors that MW exposure most likely results in acceleration of pre-existed cancer development. It is of note here that the same conclusion was drawn in epidemiological research on fast increase cancer incidence among adult population in Colorado exposed to extremely low frequency radiation [90].

The main shortcoming of the most epidemiological data, both in military studies and in mobile communication risk assessment, is a lack of a strict dose measurement of exposure. We strongly suggest that in the forthcoming epidemiological studies the correct measurement of intensity and dosage of exposure should be obligatory. The example of a large-scale epidemiological research employing personal MW dosimeters can be found in recent studies in Germany [91–94]. On the other hand, we also realize that the levels of the MW exposure in contemporary epidemiological studies, at least in those which deal with mobile communication systems, were within the official "safety limits" set by appropriate national standards and ICNIRP recommendations. Therefore, taking into account the reviewed data, we conclude that the relatively long-term (e.g., 10 years) exposure to microwaves emitted from mobile communication devices operating within "safety limits" set by current regulating bodies can be considered as a potential factor for promotion of cancer growth. Indeed, in the most studies on rodents the intensity of MW exposure was appropriately measured, and in majority of them the MW intensity was below ICNIRP safety limits. Nevertheless, majority of these studies to a greater or lesser extent demonstrated obvious carcinogenic effects after long term exposure (up to 24 months). This further emphasizes that at least under certain conditions the exposure to both pulsed and continuous MW with intensities below the current official "safety limits" can indeed promote cancer development.

In addition, experimental evidences of involvement of typical markers of carcinogenesis like overproduction of reactive oxygen species or formation of 8-OH-dG under conditions of MW exposure further indicate potential danger of this type of radiation for human health. It is important to emphasize here that experimental data, especially obtained in studies *in vitro* often reveal significant biological effects even after short-term (e.g., only a few minutes) [72] and/or extremely weak intensity of exposure to MW (by several orders of magnitude lower than in ICNIRP recommendations) [95]. Taking these data into account we strongly suggest that currently used "thermal" assessment of potential hazards of MW exposure is far from being appropriate and safe.

Taken together, we state here that nowadays there is enough convincing data to appropriately assert that the long-term exposure to low intensity electromagnetic microwaves can indeed promote cancer development. To that, the official recommendations by ICNIRP and safety limits set by many national regulatory bodies for technical devices emitting microwave radiation, first of all for mobile communication systems, must be re-assessed according to the recent alarming

data; and additional studies for unprejudiced risk assessment must be carried out. At present, we strongly suggest for a wide implementation of precautionary principle for everyday microwave exposure that implies maximum restriction of excessive exposure.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGMENTS

This study was supported by National Academy of Sciences of Ukraine (Grant No 2.2.5.349); and received a financial contribution from the European Community within the Seventh Framework Programme (FP/2007–2013) under Grant Agreement No. 229603; and was also co-financed by the South Moravian Region via SoMoPro programme.

REFERENCES

1. **Hardell L, Sage C.** Biological effects from electromagnetic field exposure and public exposure standards. Biomed Pharmacother 2008; **62**: 104–9.
2. **Breckenkamp J, Berg G, Blettner M.** Biological effects on human health due to radiofrequency/microwave exposure: a synopsis of cohort studies. Radiat Environ Biophys 2003; **42**: 141–54.
3. **Ahlbom A, Green A, Kheifets L, *et al.*** Epidemiology of health effects of radiofrequency exposure. Environ Health Perspect 2004; **112**: 1741–54.
4. **Morgan LL.** Estimating the risk of brain tumors from cellphone use: Published case-control studies. Pathophysiology 2009; **16**: 137–47.
5. **Khurana VG, Teo C, Kundi M, *et al.*** Cell phones and brain tumors: a review including the long-term epidemiologic data. Surg Neurol 2009; **72**: 205–15.
6. **Hardell L, Carlberg M, Hansson Mild K.** Epidemiological evidence for an association between use of wireless phones and tumor diseases. Pathophysiology 2009; **16**: 113–22.
7. **Kundi M.** The controversy about a possible relationship between mobile phone use and cancer. Environ Health Perspect 2009; **117**: 316–24.
8. **Leszczynski D, Xu Z.** Mobile phone radiation health risk controversy: the reliability and sufficiency of science behind the safety standards. Health Res Policy Syst 2010; **8**: 2.
9. **Yakymenko I, Sidorik E.** Risks of carcinogenesis from electromagnetic radiation of mobile telephony devices. Exp Oncol 2010; **32**: 54–60.
10. **Yakymenko I, Sidorik E, Tsybulin O.** Metabolic changes in living cells under electromagnetic radiation of mobile communication systems. Ukr Biokhim Zh 2011; **83**: 5–13.
11. **ICNIRP.** Guidelines for limiting exposure to time-varying elecrtic, magnetic and electromagnetic fields (up to 300 GHz). Health Phys 1998; **74**: 494–522.
12. **Gandhi O, Lazzi G, Furse C.** Electromagnetic absorption in the human head and neck for mobile telephones at 835 and 1900 MHz. Microwave Theory and Techniques 1996; **44**: 1884–97.
13. **de Salles AA, Bulla G, Rodriguez CE.** Electromagnetic absorption in the head of adults and children due to mobile phone operation close to the head. Electromagn Biol Med 2006; **25**: 349–60.
14. **Christ A, Gosselin MC, Christopoulou M, *et al.*** Age-dependent tissue-specific exposure of cell phone users. Phys Med Biol 2010; **55**: 1767–83.
15. **Goldsmith JR.** Epidemiological evidence relevant to radar (microwave) effects. Environ Health Perspect 1997; **105**: 1579–87.
16. **Szmigielski S.** Polish epidemiological study links RF/MW exposures to cancer. Microwave news 1985; **5**: 1–2.
17. **Szmigielski S.** Cancer morbidity in subjects occupationally exposed to high frequency (radiofrequency and microwave) electromagnetic radiation. Sci Total Environ 1996; **180**: 9–17.
18. **Robinette CD, Silverman C, Jablon S.** Effects upon health of occupational exposure to microwave radiation (radar). Am J Epidemiol 1980; **112**: 39–53.
19. **Rafnsson V, Hrafnkelsson J, Tulinius H.** Incidence of cancer among commercial airline pilots. Occup Environ Med 2000; **57**: 175–9.
20. **Gundestrup M, Storm HH.** Radiation-induced acute myeloid leukaemia and other cancers in commercial jet cockpit crew: a population-based cohort study. Lancet 1999; **354**: 2029–31.
21. **Grayson JK.** Radiation exposure, socioeconomic status, and brain tumor risk in the US Air Force: a nested case-control study. Am J Epidemiol 1996; **143**: 480–6.
22. **Zeeb H, Hammer GP, Langner I, *et al.*** Cancer mortality among German aircrew: second follow-up. Radiat Environ Biophys 2010; **49**: 187–94.
23. **Davis RL, Mostofi FK.** Cluster of testicular cancer in police officers exposed to hand-held radar. Am J Ind Med 1993; **24**: 231–3.
24. **Finkelstein MM.** Cancer incidence among Ontario police officers. Am J Ind Med 1998; **34**: 157–62.
25. **Savitz DA, Calle EE.** Leukemia and occupational exposure to electromagnetic fields: review of epidemiologic surveys. J Occup Med 1987; **29**: 47–51.
26. **Tynes T, Hannevik M, Andersen A, *et al.*** Incidence of breast cancer in Norwegian female radio and telegraph operators. Cancer Causes Control 1996; **7**: 197–204.
27. **Hardell L, Mild KH, Carlberg M.** Case-control study on the use of cellular and cordless phones and the risk for malignant brain tumours. Int J Radiat Biol 2002; **78**: 931–6.
28. **Hardell L, Mild KH, Carlberg M, *et al.*** Cellular and cordless telephone use and the association with brain tumors in different age groups. Arch Environ Health 2004; **59**: 132–7.
29. **Hardell L, Mild KH, Carlberg M, *et al.*** Tumour risk associated with use of cellular telephones or cordless desktop telephones. World J Surg Oncol 2006; **4**: 74.
30. **Hardell L, Hansson Mild K.** Mobile phone use and risk of acoustic neuroma: results of the interphone case-control study in five North European countries. Br J Cancer 2006; **94**: 1348–9; author reply 52–3.
31. **Hardell L, Carlberg M, Soderqvist F, *et al.*** Long-term use of cellular phones and brain tumours: increased risk associated with use for > or =10 years. Occup Environ Med 2007; **64**: 626–32.
32. **Hardell L, Carlberg M, Hansson Mild K.** Case-control study on cellular and cordless telephones and the risk for acoustic neuroma or meningioma in patients diagnosed 2000–2003. Neuroepidemiology 2005; **25**: 120–8.
33. **Hardell L, Carlberg M.** Mobile phones, cordless phones and the risk for brain tumours. Int J Oncol 2009; **35**: 5–17.
34. **Hardell L, Carlberg M, Mild KH.** Case-control study of the association between the use of cellular and cordless telephones and malignant brain tumors diagnosed during 2000-2003. Environ Res 2006; **100**: 232–41.
35. **Cardis E, Deltour I, Vrijheid M, *et al.*** Brain tumour risk in relation to mobile telephone use: results of the INTER-

PHONE international case-control study. Int J Epidemiol 2010; **39**: 675–94.

36. **Yakymenko I, Sidorik E, Tsybulin O, *et al.*** Potential risks of microwaves from mobile phones for youth health. Environment & Health 2011; **56**: 48–51.

37. **Sadetzki S, Chetrit A, Jarus-Hakak A, *et al.*** Cellular phone use and risk of benign and malignant parotid gland tumors — a nationwide case-control study. Am J Epidemiol 2008; **167**: 457–67.

38. **Czerninski R, Zini A, Sgan-Cohen HD.** Risk of parotid malignant tumors in Israel (1970-2006). Epidemiology 2011; **22**: 130–1.

39. **Auvinen A, Hietanen M, Luukkonen R, *et al.*** Brain tumors and salivary gland cancers among cellular telephone users. Epidemiology 2002; **13**: 356–9.

40. **Hardell L, Eriksson M, Carlberg M, *et al.*** Use of cellular or cordless telephones and the risk for non-Hodgkin's lymphoma. Int Arch Occup Environ Health 2005; **78**: 625–32.

41. **Linet MS, Taggart T, Severson RK, *et al.*** Cellular telephones and non-Hodgkin lymphoma. Int J Cancer 2006; **119**: 2382–8.

42. **Stang A, Anastassiou G, Ahrens W, *et al.*** The possible role of radiofrequency radiation in the development of uveal melanoma. Epidemiology 2001; **12**: 7–12.

43. **Hardell L, Carlberg M, Ohlson CG, *et al.*** Use of cellular and cordless telephones and risk of testicular cancer. Int J Androl 2007; **30**: 115–22.

44. **Kundi M, Hutter HP.** Mobile phone base stations-Effects on wellbeing and health. Pathophysiology 2009; **16**: 123–35.

45. **Abdel-Rassoul G, El-Fateh OA, Salem MA, *et al.*** Neurobehavioral effects among inhabitants around mobile phone base stations. Neurotoxicology 2007; **28**: 434–40.

46. **Hutter HP, Moshammer H, Wallner P, *et al.*** Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations. Occup Environ Med 2006; **63**: 307–13.

47. **Wolf R, Wolf D.** Increased incidence of cancer near a cell-phone transmitted station. In: Columbus F., editor. Trends in cancer prevention: Nova Science Publishers, Inc, 2007: 1–8.

48. **Eger H, Hagen K, Lucas B, *et al.*** Einfluss der räumlichen Nähe von Mobilfunksendeanlagen auf die Krebsinzidenz. Umwelt-Medizin-Gesellschaft 2004; **17**: 273–356.

49. **Santini R, Santini P, Danze JM, *et al.*** Study of the health of people living in the vicinity of mobile phone base stations: 1. Influences of distance and sex. Pathol Biol 2002; **50**: 369–73.

50. **Navarro E, Segura J, Portoles M, *et al.*** The Microwave Syndrome: A Preliminary Study in Spain Electromagn Biol Med 2003; **22**: 161–9.

51. **Chou CK, Guy AW, Kunz LL, *et al.*** Long-term, low-level microwave irradiation of rats. Bioelectromagnetics 1992; **13**: 469–96.

52. **Toler JC, Shelton WW, Frei MR, *et al.*** Long-term, low-level exposure of mice prone to mammary tumors to 435 MHz radiofrequency radiation. Radiat Res 1997; **148**: 227–34.

53. **Frei MR, Jauchem JR, Dusch SJ, *et al.*** Chronic, low-level (1.0 W/kg) exposure of mice prone to mammary cancer to 2450 MHz microwaves. Radiat Res 1998; **150**: 568–76.

54. **Szmigielski S, Szudzinski A, Pietraszek A, *et al.*** Accelerated development of spontaneous and benzopyrene-induced skin cancer in mice exposed to 2450-MHz microwave radiation. Bioelectromagnetics 1982; **3**: 179–91.

55. **Repacholi MH, Basten A, Gebski V, *et al.*** Lymphomas in E mu-Pim1 transgenic mice exposed to pulsed 900 MHZ electromagnetic fields. Radiat Res 1997; **147**: 631–40.

56. **Kamata H, Hirata H.** Redox regulation of cellular signalling. Cell Signal 1999; **11**: 1–14.

57. **Halliwell B, Whiteman M.** Measuring reactive species and oxidative damage in vivo and in cell culture: how should you do it and what do the results mean? Br J Pharmacol 2004; **142**: 231–55.

58. **Nemoto S, Takeda K, Yu ZX, *et al.*** Role for mitochondrial oxidants as regulators of cellular metabolism. Mol Cell Biol 2000; **20**: 7311–8.

59. **Valko M, Leibfritz D, Moncol J, *et al.*** Free radicals and antioxidants in normal physiological functions and human disease. Int J Biochem Cell Biol 2007; **39**: 44–84.

60. **Valko M, Rhodes CJ, Moncol J, *et al.*** Free radicals, metals and antioxidants in oxidative stress-induced cancer. Chem Biol Interact 2006; **160**: 1–40.

61. **Ferreira AR, Bonatto F, de Bittencourt Pasquali MA, *et al.*** Oxidative stress effects on the central nervous system of rats after acute exposure to ultra high frequency electromagnetic fields. Bioelectromagnetics 2006; **27**: 487–93.

62. **Grigoriev YG, Grigoriev OA, Ivanov AA, *et al.*** Confirmation studies of Soviet research on immunological effects of microwaves: Russian immunology results. Bioelectromagnetics 2010; **31**: 589–602.

63. **Irmak MK, Fadillioglu E, Gulec M, *et al.*** Effects of electromagnetic radiation from a cellular telephone on the oxidant and antioxidant levels in rabbits. Cell Biochem Funct 2002; **20**: 279–83.

64. **Ozgur E, Guler G, Seyhan N.** Mobile phone radiation-induced free radical damage in the liver is inhibited by the antioxidants N-acetyl cysteine and epigallocatechin-gallate. Int J Radiat Biol 2010; **86**: 935–45.

65. **Ozguner F, Altinbas A, Ozaydin M, *et al.*** Mobile phone-induced myocardial oxidative stress: protection by a novel antioxidant agent caffeic acid phenethyl ester. Toxicol Ind Health 2005; **21**: 223–30.

66. **Ozguner F, Oktem F, Ayata A, *et al.*** A novel antioxidant agent caffeic acid phenethyl ester prevents long-term mobile phone exposure-induced renal impairment in rat. Prognostic value of malondialdehyde, N-acetyl-beta-D-glucosaminidase and nitric oxide determination. Mol Cell Biochem 2005; **277**: 73–80.

67. **Sokolovic D, Djindjic B, Nikolic J, *et al.*** Melatonin reduces oxidative stress induced by chronic exposure of microwave radiation from mobile phones in rat brain. J Radiat Res (Tokyo) 2008; **49**: 579–86.

68. **Agarwal A, Desai NR, Makker K, *et al.*** Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: an in vitro pilot study. Fertil Steril 2009; **92**: 1318–25.

69. **Luukkonen J, Hakulinen P, Maki-Paakkanen J, *et al.*** Enhancement of chemically induced reactive oxygen species production and DNA damage in human SH-SY5Y neuroblastoma cells by 872 MHz radiofrequency radiation. Mutat Res 2009; **662**: 54–8.

70. **Zmyslony M, Politanski P, Rajkowska E, *et al.*** Acute exposure to 930 MHz CW electromagnetic radiation in vitro affects reactive oxygen species level in rat lymphocytes treated by iron ions. Bioelectromagnetics 2004; **25**: 324–8.

71. **De Iuliis GN, Newey RJ, King BV, *et al.*** Mobile phone radiation induces reactive oxygen species production and DNA damage in human spermatozoa in vitro. PLoS One 2009; **4**: e6446.

72. **Friedman J, Kraus S, Hauptman Y, *et al.*** Mechanism of short-term ERK activation by electromagnetic fields at mobile phone frequencies. Biochem J 2007; **405**: 559–68.

73. **Ruediger HW.** Genotoxic effects of radiofrequency electromagnetic fields. Pathophysiology 2009; **16**: 89–102.

74. **Gandhi G, Anita.** Genetic damage in mobile phone users: some preliminary findings. Indian J. Hum. Gent. 2005; **11**: 99–104.

75. **Yadav AS, Sharma MK.** Increased frequency of micronucleated exfoliated cells among humans exposed in vivo to mobile telephone radiations. Mutat Res 2008; **650**: 175–80.

76. **Lai H, Singh NP.** Acute low-intensity microwave exposure increases DNA single-strand breaks in rat brain cells. Bioelectromagnetics 1995; **16**: 207–10.

77. **Lai H, Singh NP.** Single- and double-strand DNA breaks in rat brain cells after acute exposure to radiofrequency electromagnetic radiation. Int J Radiat Biol 1996; **69**: 513–21.

78. **Ferreira AR, Knakievicz T, Pasquali MA, *et al.*** Ultra high frequency-electromagnetic field irradiation during pregnancy leads to an increase in erythrocytes micronuclei incidence in rat offspring. Life Sci 2006; **80**: 43–50.

79. **Kesari KK, Behari J, Kumar S.** Mutagenic response of 2.45 GHz radiation exposure on rat brain. Int J Radiat Biol 2010; **86**: 334–43.

80. **Diem E, Schwarz C, Adlkofer F, *et al.*** Non-thermal DNA breakage by mobile-phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro. Mutat Res 2005; **583**: 178–83.

81. **Paulraj R, Behari J.** Single strand DNA breaks in rat brain cells exposed to microwave radiation. Mutat Res 2006; **596**: 76–80.

82. **Wu W, Yao K, Wang KJ, *et al.*** Blocking 1800 MHz mobile phone radiation-induced reactive oxygen species production and DNA damage in lens epithelial cells by noise magnetic fields. Zhejiang Da Xue Xue Bao Yi Xue Ban 2008; **37**: 34–8.

83. **Schwarz C, Kratochvil E, Pilger A, *et al.*** Radiofrequency electromagnetic fields (UMTS, 1,950 MHz) induce genotoxic effects in vitro in human fibroblasts but not in lymphocytes. Int Arch Occup Environ Health 2008; **81**: 755–67.

84. **Paulraj R, Behari J, Rao AR.** Effect of amplitude modulated RF radiation on calcium ion efflux and ODC activity in chronically exposed rat brain. Indian J Biochem Biophys 1999; **36**: 337–40.

85. **Byus CV, Kartun K, Pieper S, *et al.*** Increased ornithine decarboxylase activity in cultured cells exposed to low energy modulated microwave fields and phorbol ester tumor promoters. Cancer Res 1988; **48**: 4222–6.

86. **Litovitz TA, Krause D, Penafiel M, *et al.*** The role of coherence time in the effect of microwaves on ornithine decarboxylase activity. Bioelectromagnetics 1993; **14**: 395–403.

87. **Litovitz TA, Penafiel LM, Farrel JM, *et al.*** Bioeffects induced by exposure to microwaves are mitigated by superposition of ELF noise. Bioelectromagnetics 1997; **18**: 422–30.

88. **Hoyto A, Juutilainen J, Naarala J.** Ornithine decarboxylase activity is affected in primary astrocytes but not in secondary cell lines exposed to 872 MHz RF radiation. Int J Radiat Biol 2007; **83**: 367–74.

89. **Clifford A, Morgan D, Yuspa SH, *et al.*** Role of ornithine decarboxylase in epidermal tumorigenesis. Cancer Res 1995; **55**: 1680–6.

90. **Wertheimer N, Leeper E.** Adult cancer related to electrical wires near the home. Int J Epidemiol 1982; **11**: 345–55.

91. **Roosli M, Frei P, Bolte J, *et al.*** Conduct of a personal radiofrequency electromagnetic field measurement study: proposed study protocol. Environ Health 2010; **9**: 23.

92. **Heinrich S, Thomas S, Heumann C, *et al.*** Association between exposure to radiofrequency electromagnetic fields assessed by dosimetry and acute symptoms in children and adolescents: a population based cross-sectional study. Environ Health 2010; **9**: 75.

93. **Milde-Busch A, von Kries R, Thomas S, *et al.*** The association between use of electronic media and prevalence of headache in adolescents: results from a population-based cross-sectional study. BMC Neurol 2010; **10**: 12.

94. **Thomas S, Heinrich S, Kuhnlein A, *et al.*** The association between socioeconomic status and exposure to mobile telecommunication networks in children and adolescents. Bioelectromagnetics 2010; **31**: 20–7.

95. **De Pomerai D, Daniells C, David H, *et al.*** Non-thermal heat-shock response to microwaves. Nature 2000; **405**: 417–8.

Cell Towers - Neurological; Changes of Clinically Important Neurotransmitters under the Influence of Modulated RF Fields, A Long-term Study under Real-life Conditions; Umwelt-Medizin-Gesellschaft; (Buchner & Eger); 2011

Changes of Clinically Important Neurotransmitters under the Influence of Modulated RF Fields—A Long-term Study under Real-life Conditions

Klaus Buchner and Horst Eger

This follow-up of 60 participants over one and a half years shows a significant effect on the adrenergic system after the installation of a new cell phone base station in the village of Rimbach (Bavaria).
After the activation of the GSM base station, the levels of the stress hormones adrenaline and noradrenaline increased significantly during the first six months; the levels of the precursor dopamine decreased substantially. The initial levels were not restored even after one and a half years. As an indicator of the dysregulated chronic imbalance of the stress system, the phenylethylamine (PEA) levels dropped significantly until the end of the study period.
The effects showed a dose-response relationship and occurred well below current limits for technical RF radiation exposures. Chronic dysregulation of the catecholamine system has great relevance for health and is well known to damage human health in the long run.

Keywords: cell phone base station, long-term study, stress hormones, radiofrequency radiation, GSM transmitter, far-field radiation

Introduction

Despite the distribution of numerous wireless transmitters, especially those of cell phone networks, there are only very few real-life field studies about health effects available. In 2003, the Commission on Radiation Protection was still noticing that there are no reliable data available concerning the public's exposure to UMTS radiation near UMTS base stations (1).

Since the 1960s, occupational studies on workers with continuous microwave radiation exposures (radar, manufacturing, communications) in the Soviet Union have shown that RF radiation exposures below current limits represent a considerable risk potential. A comprehensive overview is given in the review of 878 scientific studies by Prof. Hecht, which he conducted on behalf of the German Federal Institute of Telecommunications (contract no. 4231/630402) (2, 3).
As early as the 1980s, US research projects also demonstrated in long-term studies that rats raised under sterile conditions and exposed to "low-level" RF radiation showed signs of stress by increased incidences of endocrine tumors (4, 5).

Concerned by this "scientific uncertainty" about how radiofrequency "cell tower radiation" affects public health, 60 volunteers from Rimbach village in the Bavarian Forest decided to participate in a long-term, controlled study extending about one and a half years, which was carried out by INUS Medical Center GmbH and Lab4more GmbH in

Original study in German: BUCHNER K, EGER H (2011) Umwelt-Medizin-Gesellschaft 24(1): 44-57.

Zusammenfassung

Veränderung klinisch bedeutsamer Neurotransmitter unter dem Einfluss modulierter hochfrequenter Felder - Eine Langzeiterhebung unter lebensnahen Bedingungen

Die vorliegende Langzeitstudie über einen Zeitraum von eineinhalb Jahren zeigt bei den 60 Teilnehmern eine signifikante Aktivierung des adrenergenen Systems nach Installation einer örtlichen Mobilfunksendeanlage in Rimbach (Bayern).

Die Werte der Stresshormone Adrenalin und Noradrenalin steigen in den ersten sechs Monaten nach dem Einschalten des GSM-Senders signifikant; die Werte der Vorläufersubstanz Dopamin sinken nach Beginn der Bestrahlung erheblich ab. Der Ausgangszustand wird auch nach eineinhalb Jahren nicht wieder hergestellt. Als Hinweis auf die nicht regulierbare chronische Schieflage des Stresshaushalts sinken die Werte des Phenylethylamins (PEA) bis zum Ende des Untersuchungszeitraums signifikant ab. Die Effekte unterliegen einem Dosis-Wirkungs-Zusammenhang und zeigen sich weit unterhalb gültiger Grenzwerte für technische Hochfrequenzbelastung. Chronische Dysregulationen des Katecholaminsystems sind von erheblicher gesundheitlicher Relevanz und führen erfahrungsgemäß langfristig zu Gesundheitsschäden.

Schlüsselwörter: Mobilfunk-Basisstationen, Langzeituntersuchung, Stresshormone, Mobilfunkstrahlung, Fernfeld

in cooperation with Dr. Kellermann from Neuroscience Inc.[1].

Common risk factors such as external toxic agents, parameters of the catecholamine system (6) were determined prior to the activation of the GSM transmitter and followed up in three additional tests for a period of more than 18 months. The informed consent of all participants included the condition that the data were to be published anonymously.

-------------------------------- Materials and Methods

Study Setting and Selection of Study Subjects

In spring 2004, a combined GSMD1 and GSMD2 cell transmitter (900 MHz band) was installed on Buchberg mountain in D-93485 Rimbach (Lower Bavaria) with two sets of antenna groups each. The installation height of the antennas for both systems is 7.9 m; the horizontal safety distance along the main beam direction is 6.3 or 4.3 m, respectively. At the same tower, there is also a directional antenna at 7.2 m (7).

Shortly after it had become known that the wireless transmitters were to be installed, all inhabitants of Rimbach had been asked to participate in a mass screening. The municipality has approximately 2,000 inhabitants. In 60 volunteers (27 male, 33 female) aged between 2 and 68, the levels of adrenaline, noradrenaline, dopamine, and PEA (phenylethylamine)—which cannot be consciously regulated—were determined in their urine at the end of January/beginning of February 2004 (shortly before the activation of the antennas and the RF emissions beginning) as well as in July 2004, in January 2005, and in July 2005.

Most of these study participants signed up immediately after an informational gathering in late January 2004, at which the course of action by the cell phone service providers was criticized. Others signed up following a call for participation in the local paper. Since Rimbach is a small municipality, mouth-to-mouth propaganda also played a role. Participation was made attractive to the volunteers because a lab test that usually would be very expensive was offered for a small fee. Since the study required to show the status of the biological parameters over a given time period, only those study subjects participating in all four tests are included.

The data presented below come primarily from volunteers who have a certain interest in the life of their community and their health. Other persons joined the stress hormone investigation because of the recommendation of, or request by, their fellow citizens. This does not meet the requirements for a random sample. The result of this study, however, is hardly affected because Rimbach is a very small municipality. Therefore, the social contacts that lead to participation are very important. Most probably they do not affect the blood parameters. Furthermore, numerous large families participated as a whole whereby the health status of the individual family members did not play any role. For this reason, but especially because of the population structure, the study includes many children but only a few adolescents and young adults: there are hardly any opportunities for occupational training in Rimbach. In contrast, the municipality is attractive to young families with many children.

Sample Collection

The second morning urine was collected at INUS Medical Center on Mondays between 9:00 and 11:00 a.m. We made sure that each participant's appointment was always scheduled for the same time and that the time of breakfast or the state of fasting was the same for each participant at all tests. On the same day, the samples were sent by express to *Labor Dr. Bieger* in Munich where they were processed. In addition, samples were also sent to a laboratory in Seattle for control analyses (8-11).

Medical History

Medical doctors of the INUS Medical Center took a thorough medical history of each participant. At the initial test, the following data were also gathered: exact address, average time spent at home, indoor toxins, stress due to heavy-traffic roads, and the number of amalgam fillings. The latter number also included fillings that had already been removed. A nine-year-old child was noted to be electro-

1) INUS Medical Center, Dr. Adam-Voll Str. 1, 93437 Furth im Wald, Tel.: 09973/500 5412, www.inus.de; Lab4more GmbH, Prof. Dr. W. Bieger, Paul-Heyse-Straße 6, 80336 München, Tel.: 089/54321 730, info@lab4more.de; NeuroScience Inc., Dr. Kellermann, 373 280th Street - Osceola, WI 54020 - USA, Tel.: +1/715/294-2144, www.neuroscienceinc.com.

sensitive to the effects of household wiring and connected appliances. All other study participants declared themselves to be not electrosensitive.

When taking their medical history, participants were also questioned about subjective symptoms and chronic diseases at the start of the study and during its course; if overweight, this was also noted. In this study, overweight in adults is defined as a weight greater than the "body height in cm minus 100 plus 5 kg tolerance."

Consistency checks for the parameter "overweight," however, indicate that—especially with regard to children—different criteria have been applied during the taking of the medical history. These data, therefore, can only serve as a reference point. They are listed here anyhow since they can provide suggestions for further studies.

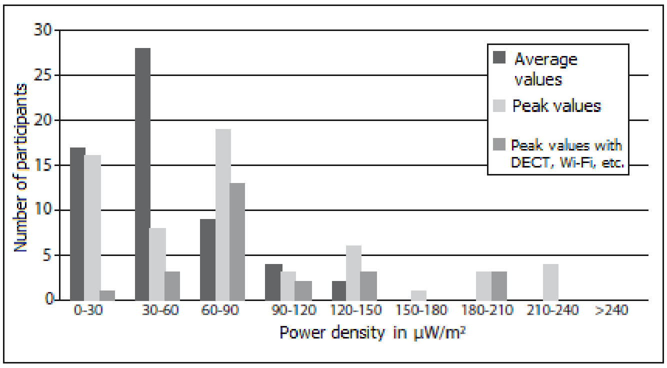


Fig. 1: Classification of participants based on average or peak value of the GSM power density level

All atopic disorders such as:

1. Hay fever, neurodermatitis, allergies, asthma, eczema are referred to as "chronic disorders;" as well as
2. All chronic inflammations such as interleukin- or COX-2-mediated problems;
3. All autoimmune diseases such as rheumatism, multiple sclerosis (MS);
4. All chronic metabolic disorders such as diabetes, liver diseases, intestinal diseases, kidney diseases.

Out of the 16 chronically affected participants 12 had allergies.

It was also asked whether there were DECT, Wi-Fi, or Bluetooth devices in the house or apartment during the study period from late January 2004 until July 2005. Also included were those devices present only for part of the study period, but not those turned off at night.

Exposure Level Measurements

For the most part, Rimbach municipality is located at one side of a narrow V-shaped valley. The cell phone base station is situated almost right across from the village center on the other side. RF radiation levels were measured at the outside of the residences of all study participants, wherever possible with direct line of sight of the transmitter. Because the municipality is located on a slope, great differences were noted inside homes—depending on whether or not a line of sight to the transmitter existed. In three cases, it was possible to measure the exposure levels at the head end of the bed. In these cases, the peak value of the power density was lower by a factor of 3.5 to 14 compared to measurements in front of the house with direct line of sight to the transmitter. The exact location of DECT, Wi-Fi, and Bluetooth base stations (if present) as well as possible occupational exposures, etc. were not determined by most participants.

At first, the measurements were taken with a broadband RF meter HF38B of Gigahertz Solutions, for which the manufacturer guarantees an error margin of max. ±6 dB (+ 7 decimal places; but this error can be mostly eliminated by selecting the appropriate measurement range). However, an inspection revealed that the error margin was less than ±3 dB. In addition, the broadband RF meter HF59B (±3 dB, ±5 decimal places) was used at several points. With this RF meter, relevant frequencies can be analyzed with variable filters, the ELF modulation frequencies via fast Fourier analysis.

By using broadband RF meters, the testing effort and expense are reduced compared to spectrum analyzers. Thus, it was possible to take measurements at a greater number of points, and as a result, it was easier to determine the maxima and minima of the power density levels. Furthermore, the accuracy of high-quality broadband RF meters is similar to that of spectrum analyzers.

In this study, only cell phone signals are considered: not DECT, Wi-Fi, or Bluetooth devices inside homes or emissions from broadcast or TV stations at *Hohenbogen*, a mountain above Rimbach. For the most part, the emissions from the latter transmitters remained stable during the study period, whereas the focus of this study is on changes in exposure levels. For almost all sample measurements, the portion of the exposure due to the transmitter at *Hohenbogen* was at maximum 35 µW/m^2 (peak value). It was higher in the residences of only two study participants: 270 µW/m^2 (average) or 320 µW/m^2 (peak), respectively. At these residences, the GSM exposure was approximately 10 µW/m^2.

For the assessment, the peak values of the signals are used because, in the case of GSM radiation, they are less dependent on the usage level than average values. The peak value of the power density for all study participants from Rimbach was on average 76.9 µW/m^2 (Tab. 1).

In Figure 1 the exposure of the participants is given as power density levels in increments of 30 µW/m^2.

Classification of Participant Group and Exposure Levels

Sixty persons participated in the study; their age distribution is shown in Figure 2 according to year groups. In order to capture the effect of the cell phone base station, other environmental factors must be excluded as much as possible. It is vitally important to ensure that no major differences between high-exposure and low-exposure persons influenced the results.

Original study in German: BUCHNER K, EGER H (2011) Umwelt-Medizin-Gesellschaft 24(1): 44-57.

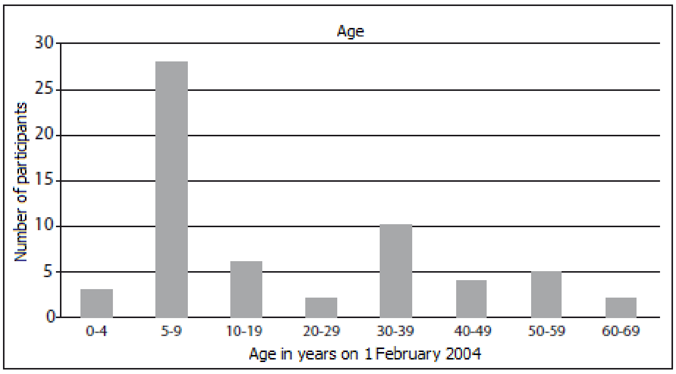


Fig. 2: Age distribution of study participants on 1 February 2004

	All	<=60 µW/m²	60-100 µW/m²	>100 µW/m²
Participants	60	24	20	16
Power density, avg (µW/m²)	76.9	21.7	68.1	170.7
Healthy adults	20	9	5	6
Sick adults	9	6	2	1
Healthy children	24	9	7	8
Sick children	7	0	6	1
Overweight	14	7	3	4
Amalgam number	12	5	3	4
Evaluation of amalgam/person	120	76.4	32.7	240
Street	8	0	8	0
Indoor toxins	17	7	6	4
DECT, Wi-Fi, Bluetooth	25	4	14	7

Tab. 1: Data on the 60 study participants who are classified into exposure groups 0 - 60 µW/m², 60 - 100 W/m², and above 100 µW/m², based on relevant peak values of GSM exposure in front of their residence.

Additional information:

Power density, avg (µW/m²) means: average peak value of GSM exposure level in the relevant category;
Healthy adults: adults without chronic diseases. Participants who were born after 1 February 1994 are referred to as children, all others as adults;
Sick adults: adults with chronic diseases;
Healthy children: children without chronic diseases;
Sick children: children with chronic diseases;
Overweight: see text;
Amalgam number: number of participants who had at least one amalgam filling (which may have been removed prior to the study period);
Evaluation of amalgam/person: For each tooth with an amalgam filling of a participant, the size of the filling (values from 1 to 3) is multiplied with the number of years this filling has been placed prior to the date of the initial test of this study (rounded up to the nearest whole number). The value in the table is the sum of these numbers for all amalgam fillings of a person in the respective category divided by the number of participants with amalgam fillings (= "amalgam number");
Street: number of participants who live at a busy street;
Indoor toxins: number of participants who have had contact with toxins, varnishes, preservatives, etc. at home or at work;
DECT, Wi-Fi: number of persons who had DECT, Wi-Fi, Bluetooth or the like at home at the end of January 2004 or later.

As shown in Table 1, the group with exposure levels greater than 100 µW/m² included fewer chronically ill persons and fewer residences at heavy-traffic roads, but considerably higher amalgam exposures by dental fillings compared to the average of the participants. These differences, however, cannot explain the observed development of the blood parameters as will be shown further below. It should also be noted that the number of children in the group of <= 60 µW/m² is considerably lower than in the other two groups.

Statistics

Because of the large individual differences in blood values, their asymmetrical distribution, and because of the many "outliers," the assessment presented here focuses on the following problem: "Did the level of a given substance predominantly increase (or decrease, respectively) in the test subjects?" For this problem, the so-called signed-rank paired Wilcoxon test (12) is applied. How to determine the confidence intervals of medians is described in an easy-to-understand form in (13).

Due to the rather large differences in individual values, we refrained from carrying out additional statistical analyses, especially those with parametric methods.

--- Results

1 Clinical Findings

Adrenaline, noradrenaline, and dopamine as well as phenylethylamine (PEA) levels were determined at the time when the medical history was taken at INUS Medical Center. Out of the 60 participants, eleven had sleep problems until the end of 2004. During the study period (until July 2005), eight additional cases with these problems were reported. At the end of January 2004, only two participants complained about headaches; eight additional cases were reported thereafter. For allergies, there were eleven cases in the beginning and 16 later; for dizziness five and eight; and for concentration problems ten and fourteen. Due to the limited number of participants, no meaningful statements can be made about changes during the study period regarding the conditions tinnitus, depression, high blood pressure, autoimmune diseases, rheumatism, hyperkinetic syndrome, attention deficit hyperactivity disorder (ADHD), tachycardia, and malignant tumors. (Tab. 2)

Symptoms	Before activation of transmitter	After activation of transmitter
Sleep problems	11	19
Headache	2	10
Allergy	11	16
Dizziness	5	8
Concentration problems	10	14

Tab. 2: Clinical symptoms before and after activation of transmitter

2 Adrenaline

The adrenaline level trends are shown in Figure 3. After the activation of the transmitter from January until July 2004, a clear increase is followed by a decrease. In participants in the exposure category above 100 μW/m², the decrease is delayed.

Since the distribution of the adrenaline levels is very asymmetrical as shown in Figure 4, the median values are better suited for evaluation than the average values. However, there is no significant difference between the trend of the median and the trend of the average values (Tab. 3). But it stands out that, in the lowest exposure group with a power density below 60 μW/m², median values do not decrease between July 2004 and January 2005.

The statement "The adrenaline values of study subjects increased after the activation of the transmitter, i.e. between January and July 2004" is statistically confirmed ($p<0.002$), as well as the statement "The adrenaline level of the study participants decreased from July 2004 to July 2005" ($p<0.005$). In the lowest exposure group, the increase is the smallest. Until the end of the study period, these values do not drop.

A certain dose-response relationship can be observed for the increase in adrenaline levels from January 2004 until July 2004. The increase in medians was 2.3 μg/g creatinine for all subjects. At an RF radiation level up to 60 μW/m², creatinine was 1.0 μg/g, and by contrast, for power density levels between 60-100 μW/m² it was 2.6 μg/g.

For subjects in the exposure group above 100 μW/m², creatinine levels were found to be 2.7 μg/g, i.e. this value did not increase. We refrain from any additional statistical analysis because, as shown further below, the increase in adrenaline levels was mainly observed in children and chronically ill participants whose numbers were not sufficient to be broken down into further subgroups.

		January 2004	July 2004	January 2005	July 2005
All	Average	8.56	10.79	8.84	9.14
	Median	7.44	9.75	8.40	7.45
	CI	5.9 - 8.4	6.6 - 11.7	6.1 - 10.0	6.5 - 9.6
0-60 μW/m²	Average	8.9	10.3	7.7	9.0
	Median	6.4	7.4	7.8	7.4
	CI	3.8 - 10.3	4.6 - 13.2	3.4 - 9.4	5.5 - 11.1
60-100 μW/m²	Average	7.9	10.4	8.4	9.0
	Median	7.4	10.2	8.1	7.2
	CI	5.3 - 10.0	6.6 - 12.8	5.0 - 11.2	6.4 - 9.7
>100 μW/m²	Average	8.9	12.0	11.1	9.6
	Median	8.2	10.9	10.6	8.6
	CI	5.3 - 10.9	5.7 - 19.6	5.8 - 15.2	4.9 - 13.4

Tab. 3: Results for adrenaline levels in μg/g creatinine
CI = 95% confidence interval of median

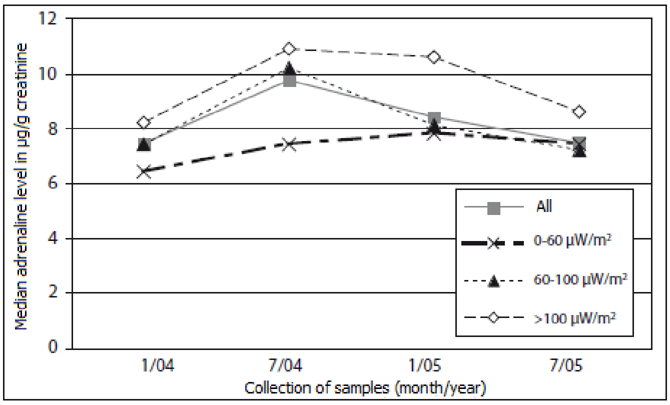


Fig. 3: Median adrenaline levels for all participating citizens of Rimbach whose cell phone base station exposure was above 100 μW/m², between 60 and 100 μW/m², or up to 60 μW/m². The power density levels refer to peak values of the GSM radiation exposure in front of a given residence.

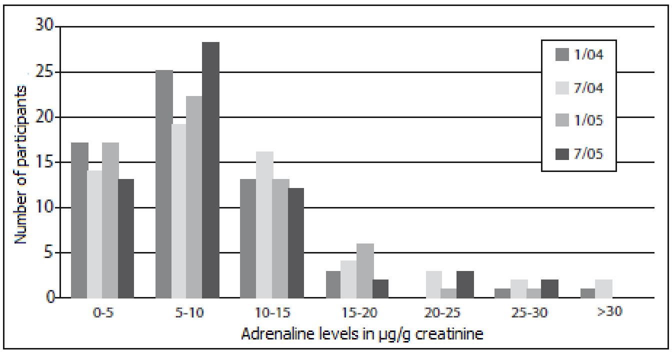


Fig. 4: Distribution of adrenaline levels in μg/g creatinine

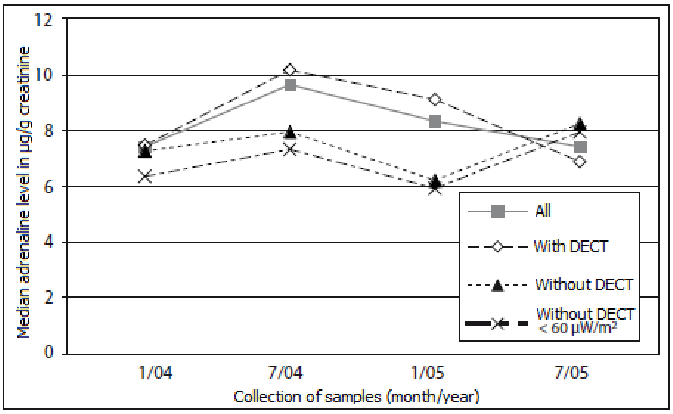


Fig. 5: Median adrenaline levels for all participating citizens of Rimbach who have a DECT phone, Wi-Fi, Bluetooth, or similar device, for those who do not have such wireless devices, and for the lowest exposure group without indoor wireless transmitters and with a GSM power density level up to 60 μW/m².

The impact of indoor wireless devices such as DECT, Wi-Fi, and Bluetooth (the latter are not specifically mentioned in the graphs) are shown in Fig. 5. Within the first year after the activation of the GSM transmitter, i.e. until and including January 2005, the group with indoor wireless devices shows the strongest responses.

Original study in German: BUCHNER K, EGER H (2011) Umwelt-Medizin-Gesellschaft 24(1): 44-57.

It is possible that in the less exposed subjects seasonal fluctuations or other factors such as "overshooting" of the values could have played a role.
It should be noted here that both the average as well as the median adrenaline values increased after the activation of the transmitter and decreased again after one year. This, however, only applies to exposure levels >60 μW/m². Chronically ill subjects and children showed especially strong responses; except for some "outliers," no effect was observed in healthy adults.

The adrenaline level of overweight subjects and those with an amalgam burden hardly changed during the study period (Fig. 6). In contrast, chronically ill subjects showed especially strong responses above average. In fact, the increase in the median values between January and July 2004 for all study subjects was predominantly caused by children and chronically ill subjects; adults without any chronic disease show a flat curve. During this period, an increased adrenaline level between 5 and 10.3 was measured in three healthy adults. Because of these "outliers," the average values for healthy adults clearly increased in contrast to the median values.

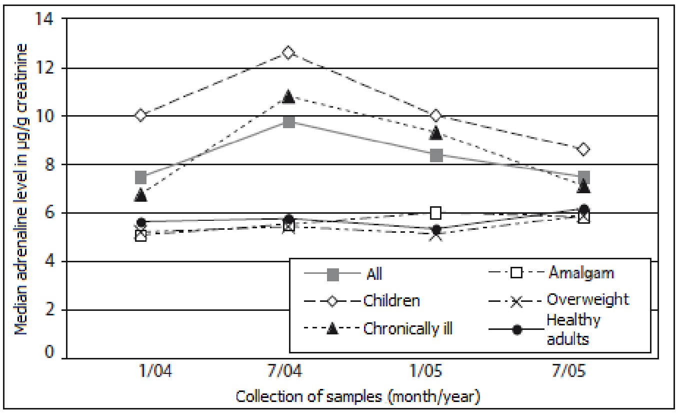


Fig. 6: Median adrenaline levels for participating children, for chronically ill subjects, for those with amalgam burden, and overweight subjects in Rimbach in comparison to the median levels of all study subjects and adults without chronic disease

The lower sensitivity of subjects with an amalgam burden can be explained by the fact that the effect occurs more often in children and that children according to our definition are younger than 10 years. They have hardly any fillings with amalgam.

3 Noradrenaline

The results for noradrenaline are similar to those for adrenaline (Tab. 4, Fig. 7). The statement that individual noradrenaline levels from January to July 2004 increased is statistically well supported with p<0.001. The fact that the levels dropped between July 2004 and July 2005 is also well supported with p<0.0005. Like in the case of adrenaline, the period under investigation is July 2004 to July 2005 to take the delayed decrease in the high exposure group into consideration. According to Table 4, the median of all noradrenaline levels increased from January to July 2004 for 11.2 μg/g creatinine; for exposures up to 60 μW/m², there were 2.2 μg/g creatinine, at 60-100 μW/m² 12.4 μg/g creatinine, and above 100 μW/m² 12.3 μg/g creatinine. As in the case of adrenaline, the increase for the last two groups is almost the same. Again, it is not possible to statistically verify a dose-response relationship. In Figure 7, a dose-response relationship

		January 2004	July 2004	January 2005	July 2005
All	Average	55.8	64.9	57.7	55.7
	Median	49.8	61.0	52.2	53.5
	CI	44.3-59.1	53.3-72.2	45.0-60.3	41.9 -60.5
0-60 μW/m²	Average	54.7	59.3	56.5	53.5
	Median	45.2	47.4	48.7	48.1
	CI	35.1-67.8	36.3-75.6	40.1-60.0	36.3-65.6
60-100 μW/m²	Average	51.4	63.6	49.1	55.9
	Median	47.5	59.9	45.8	54.8
	CI	38.0-59.1	53.1-74.8	40.5-58.4	34.9-66.5
>100 μW/m²	Average	62.9	74.9	70.1	58.8
	Median	58.8	71.1	71.6	56.3
	CI	49.9-87.3	54.9-91.6	48.7-89.1	36.9-81.6

Tab. 4: Results for the noradrenaline levels in μg/g creatinine
CI = 95% confidence interval of the median

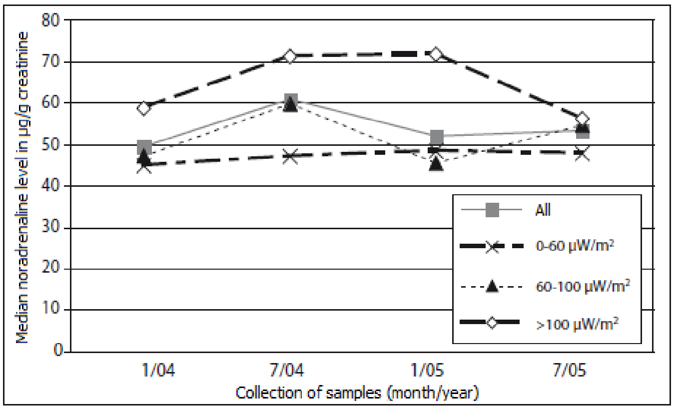


Fig. 7: Median noradrenaline levels in all participating citizens of Rimbach as a function of GSM power density levels (peak values)

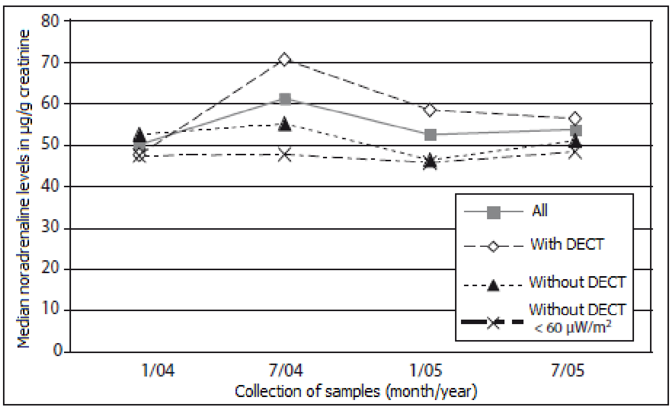


Fig. 8: Median noradrenaline values for subjects who had a DECT phone or other wireless devices at home, for those without indoor wireless devices, as well as for subjects without indoor wireless devices and with a GSM radiation exposure up to 60 μW/m² (peak value measured in front of residence)

is seen, whereby the dot-dashed line serves as reference for persons with very low exposures. It stands out that the "recovery period," i.e. the decrease in values in 2005, drags on for longer in subjects in the exposure group with GSM radiation levels above 100 µW/m². This also corresponds with the behavior of the adrenaline levels.

In comparison with adrenaline, noradrenaline plays a somewhat greater role in residences where wireless devices existed before the beginning of this study (Fig. 8).

The trend in Figure 9 shows that children and chronically ill subjects in contrast to overweight subjects express strong responses to cell tower radiation. The ratios, however, are not as clearly visible as with adrenaline. Especially in overweight subjects, they indicate a slow response to GSM radiation.

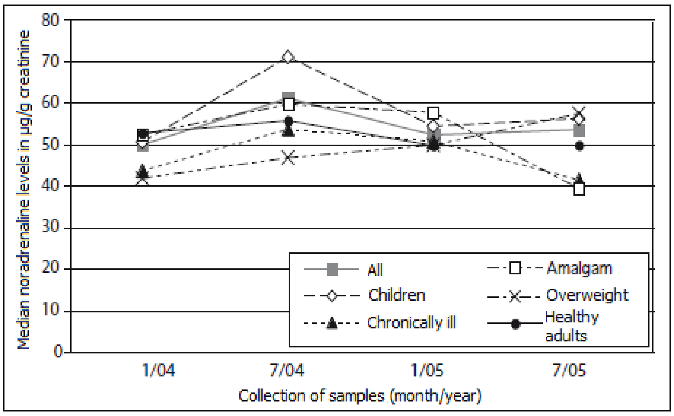


Fig. 9: Median noradrenaline levels of children, chronically ill subjects, those with amalgam burden and overweight subjects in Rimbach in comparison to the median values of all study subjects and healthy adults

Noradrenaline and adrenaline, however, responded very similarly.

4 Dopamine

For dopamine, inverse effects to those for adrenaline and noradrenaline were observed. The median dopamine levels decreased from 199 to 115 µg/g creatinine between January and July 2004 (Tab. 5). The fact that the dopamine levels of the study subjects decreased during this period is highly significant ($p<0.0002$). Thereafter, the median increased again: In January 2005, it was at 131 µg/g creatinine, in July of this year 156. This increase is also significant (for increase between July 2004 and July 2005 $p<0.05$).

This, too, is a dose-response relationship: from January to July 2004, the median for all subjects decreased for 84 µg/g creatinine, in the exposure group up to 60 µW/m² for 81, in the exposure group above 100 µW/m² even 153 µg/g (see Tab. 5 and Fig. 10). This dose-response relationship is statistically significant based on the signed-rank Wilcoxon test (12) with $p<0.025$. The following statement applies: "The decrease in dopamine levels for exposure levels up to 100 µW/m² is smaller than at exposure levels above 125 µW/m²."

In subsequent laboratory tests, the dopamine levels do not return to the same level as in January 2004. From Figure 11, it is obvious that the correlation with prior exposures to indoor wireless devices is small.

		January 2004	July 2004	January 2005	July 2005
All	Average	233	158	138	164
	Median	199	115	131	156
	CI	168-273	86-160	111-153	145-175
0-60 µW/m²	Average	217	183	130	148
	Median	189	108	116	147
	CI	142-273	80-254	90-157	129-167
60-100 µW/m²	Average	242	161	140	178
	Median	223	150	131	175
	CI	137-335	94-168	93-164	126-207
>100 µW/m²	Average	244	115	147	170
	Median	244	91	151	156
	CI	139-316	48-202	117-169	138-209

Tab. 5: Results for dopamine levels in µg/g creatinine
CI = 95% confidence interval of median

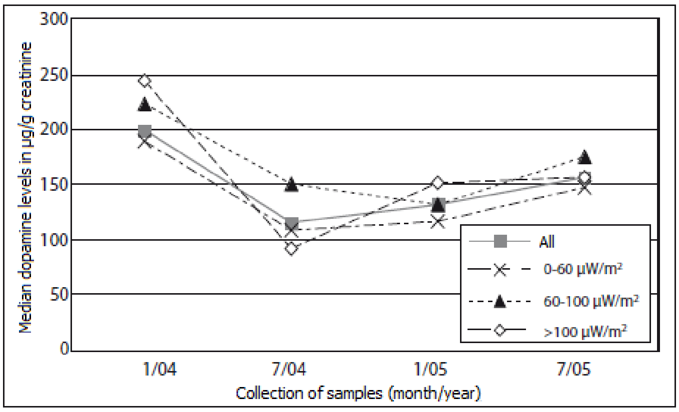


Fig. 10: Median dopamine levels for different GSM power density levels

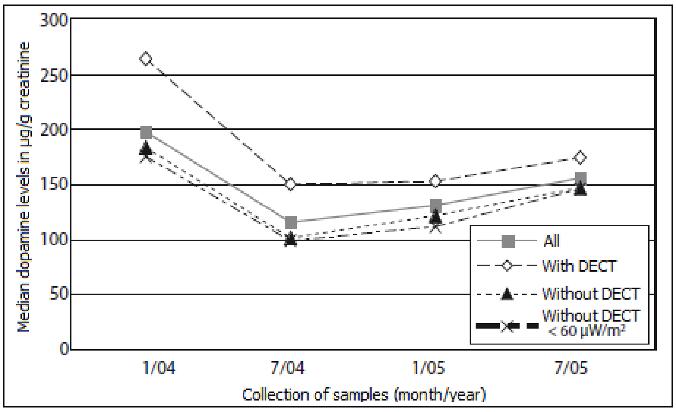


Fig. 11: Median dopamine levels for all participating citizens of Rimbach, for those with and without DECT phone, Wi-Fi, or Bluetooth, and for those without indoor wireless devices who had a GSM exposure level below 60 µW/m² (peak value).

It is to be emphasized that the lowest exposure group without such indoor wireless devices and with a GSM power density level < 60 µW/m^2 responds almost as strongly as all other study subjects. This is consistent with the data in Figure 10: the data suggest that the effect of the radiation on the dopamine levels can already be observed at very low power density levels; however, it still can increase at levels above 100 µW/m^2.

Figure 12 shows that the radiation effect is somewhat more pronounced in children compared to the average, i.e. the gradient of the curves between the first two data points is somewhat greater. However, the difference is far too small to be statistically significant.

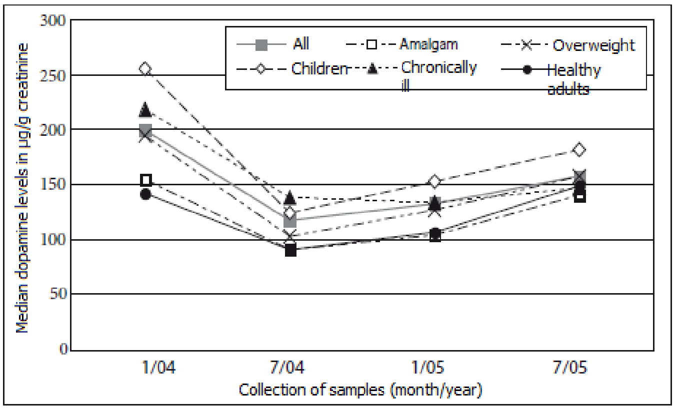


Fig. 12: Median dopamine levels of children, the chronically ill, with amalgam burden, overweight subjects, and healthy adults in Rimbach

In summary, dopamine levels decreased after the activation of the GSM transmitter and were not restored to the initial level over the following one and a half years. A significant dose-response relationship is observed. In children, the decrease is somewhat more pronounced than in adults.

5 Phenylethylamine (PEA)

Phenylethylamine (PEA) levels respond more slowly to the radiation compared to the substances investigated so far (Tab. 6, Fig. 13). Only in the exposure group above 100 µW/m^2 GSM radiation do the PEA levels decrease within the first six months. Thereafter, hardly any differences can be discerned between PEA values of the various power density levels investigated here.

The decrease of PEA levels between July 2004 and July 2005 is highly significant ($p<0.0001$)

Similar to adrenaline and noradrenaline, a previous exposure to indoor wireless devices intensifies the effect of the GSM radiation (see Fig. 14). The subjects of the low-exposure groups without indoor wireless devices do respond in a time-delayed fashion, but after six months they respond just as clearly as the subjects of the highest exposure group. In this regard, the PEA levels behave like those of dopamine in contrast to adrenaline and noradrenaline, which only respond to stronger fields.

		January 2004	July 2004	January 2005	July 2005
All	Average	725	701	525	381
	Median	638	671	432	305
	CI	535 -749	569 - 745	348 - 603	244 - 349
0-60 µW/m^2	Average	655	678	523	329
	Median	604	653	484	243
	CI	477 - 835	445 - 835	279 - 675	184 - 380
60-100 µW/m^2	Average	714	699	535	451
	Median	641	678	426	330
	CI	492 - 746	569 - 790	310 - 804	293 - 438
>100 µW/m^2	Average	843	739	514	371
	Median	780	671	413	305
	CI	451 - 1144	334 - 822	338 - 748	157 - 513

Tab. 6: Results for phenylethylamine (PEA) levels in ng/g creatinine
CI = 95% confidence interval of median

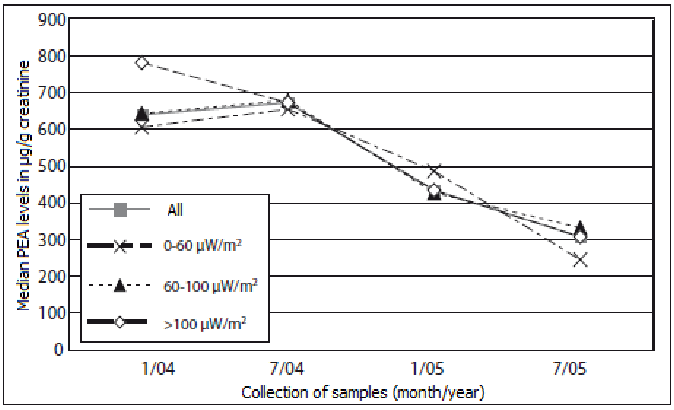


Fig. 13: Median phenylethylamine (PEA) levels for various GSM power density levels

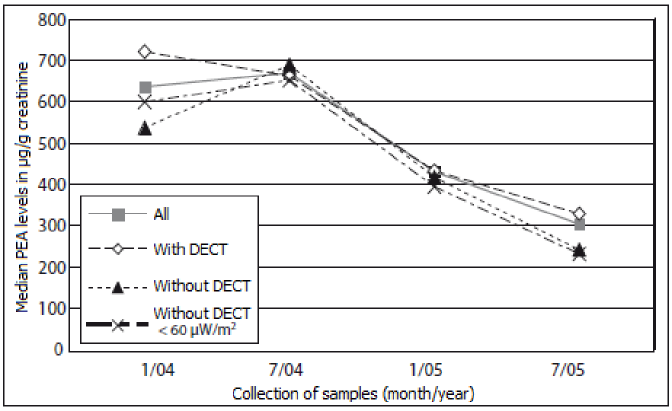


Fig. 14: Median phenylethylamine (PEA) concentrations in µg/g creatinine of subjects with and without indoor wireless devices at home and subjects without indoor wireless devices with a GSM power density level below 60 µW/m^2

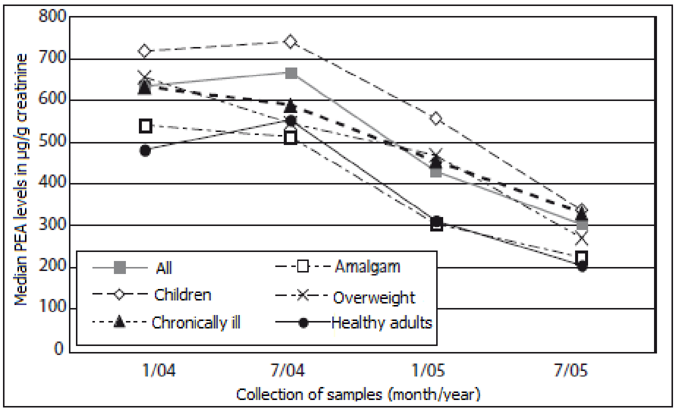


Fig. 15: Median phenylethylamine (PEA) concentrations in µg/g creatinine of children, the chronically ill, with amalgam burden, and overweight subjects, as well as health adults in Rimbach

In children, the effect of GSM radiation on their PEA levels is no greater than in the average of the study subjects; healthy adults also do not respond substantially differently. In contrast to the other substances looked at so far, the group of overweight subjects does respond particularly rapidly to PEA.

------------------------------------ Summary of Results

Adrenaline and noradrenaline levels increase during the first six months after the GSM transmitter had been activated; thereafter, they decrease again. After an exposure period of one and a half years, the initial levels are almost restored. Only at power density levels above 100 µW/m^2 is this decrease delayed for several months. In contrast, dopamine levels decrease substantially after the exposure begins. Even after one and a half years, the initial levels are not restored. Six months after the activation of the transmitter, PEA levels decrease continuously over the entire exposure period. Only in the exposure group above 100 µW/m^2 is this effect observed immediately. All findings were observed well below current exposure limits (14).

Wireless devices used at home such as DECT, Wi-Fi, and Bluetooth amplify the effect of the GSM radiation. In the case of adrenaline and noradrenaline, almost exclusively children and chronically ill subjects (here mostly subjects with allergies) are affected. However, the response of chronically ill subjects to dopamine and the response of children to PEA are very similar to those found in the average of the study subjects. Except for PEA, overweight subjects show only very weak responses to GSM radiation.

-- Discussion

Catecholamine System and Phenylethylamine (PEA)

The survival of mammals depends on their ability to respond to external sources of stress. An established, well-researched axis of the human stress system represents the catecholamine system (6, 15, 16). It can be activated by psychic or physical stressors. Impulses mediated by nerves are responsible for an induction of the catecholamine biosynthesis at the level of tyrosine hydroxylase as well as dopamine beta-hydroxylase, whereby the effect is based on an induction of both enzymes. Many biochemical regulatory mechanisms tightly control catecholamine synthesis (8, 15, 17). Chronic dysregulation always leads to health problems in the long run. The development of high blood pressure under continuous stress serves as a clinical example; so-called "beta blockers" directly block the action of adrenaline and noradrenaline on the target receptors, and it is impossible to imagine medication-based therapy without them (15).

PEA can be synthesized from the essential amino acid phenylalanine either via tyrosine, dopamine, noradrenaline, and adrenaline or via a direct biochemical path (15) (Fig. 16). The sympathetic-mimetic effect of PEA was first described by Barger in 1910 (18).

PEA is also synthesized from phenylalanine and is considered a superordinate neuromodulator for the regulation of catecholamine synthesis (19-22).

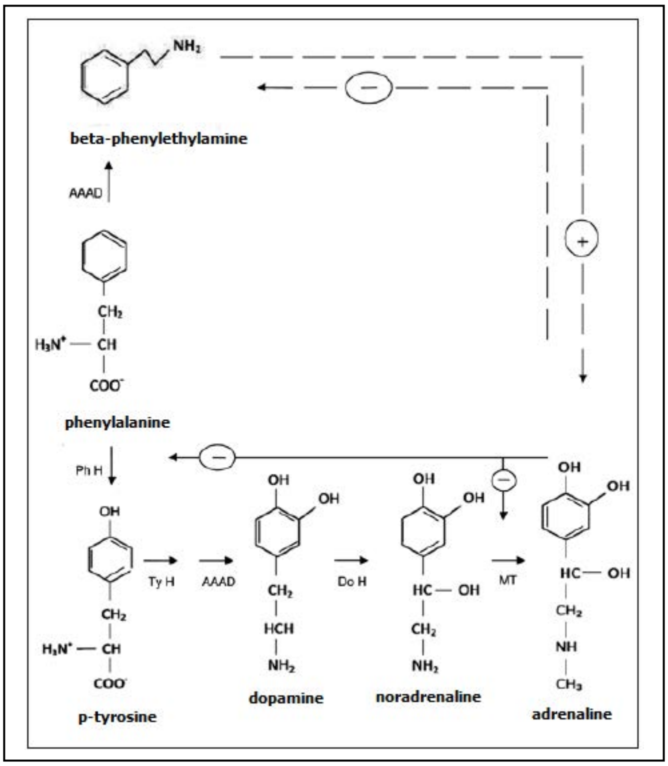


Fig. 16: Chemical structure of derivatives of the essential amino acid phenylalanine and the simplified synthesis pathways of catecholamines or phenylethylamine, respectively, simplified according to Löffler (15).

Abbreviations
AAAD: aromatic l-amino acid decarboxylase,
DoH: dopamine beta-hydroxylase,
PhH: phenylalanine hydroxylase,
MT: n-methyltransferase,
TyH: tyrosine hydroxylase
—(—)— ---- known feedback loop, - - (---) - - postulated feedback loop

In 1976, Zeller described the physiological relationships (23) and points out that PEA is released by the brain via electrical stimulation (24).

The effect mechanism of PEA in the catecholamine system is the center of current pharmaceutical research efforts. In molecular biological terms, intracellular TAAR (trace amine-associated receptor) G-protein-coupled receptors that mediate modulatory effects of PEA are verified (20).

For high nanomolar to low micromolar PEA concentrations, in vivo studies have shown amphetamine-like effects. During an increase of PEA, an increased amount of noradrenaline and dopamine is also released and the reuptake of these substances is impaired (25, 26).
According to Burchett, the following effects of PEA amplifying the catecholamine effect are assumed to be known: Direct agonist action via increased release of transmitters, reuptake inhibition, and stimulation of transmitter synthesis as well as inhibition of monoamine oxidase (MAO) (19). PEA's high lipophilia—a prerequisite for the permeability of membrane barriers such as the blood-brain barrier—is of note here; PEA levels in the brain, serum, and urine correlate quite well (10, 21, 25, 27).

The clinical relevance of changed PEA levels is well documented for mental illnesses. Endogenous depression is associated with lowered PEA levels, whereby the transition from depression to maniac episodes is accompanied by an increase in PEA levels (28-32).

The therapeutic increase in the PEA level has a positive impact on the course of the disease. Phenylalanine improves the effectiveness of antidepressants; PEA by itself is a good antidepressant—effective in 60% of the cases of depression.

In persons with ADD/ADHD (attention deficit hyperactivity disorder), PEA levels are substantially lower; the ADHD treatment with methylphenidate (Ritalin®) normalizes PEA excretion in the urine of responders (33, 34).

Contributing Factors

Laboratory tests of catecholamine have been established for years. Increased values are found in disorders such as pheochromocytoma, neuroblastoma, and arterial hypertension, whereby it is impossible for a subject to consciously regulate these values. Especially urine tests offer a sufficient level of sensitivity and specificity because urine contains 100 to 1000 times higher levels than blood plasma. The intraindividual variation coefficient ranges from 7% to 12% from one day to another; stored under appropriate conditions, the stability of the samples can be guaranteed without problems (8).

In Rimbach, urine samples were always collected at the same time of the day so that a circadian dependence could be ruled out. Other contributing factors such as increased physical activity as well as large meals were also ruled out by collecting the urine in the morning. Seasonal factors of the samples collected twice in winter and summer should have been reflected as undulating levels in the testing results. Only in the adrenaline levels of the lower exposure groups (Fig. 5) can such a corresponding correlation be found. All other data did not indicate any seasonal influences.

In the study presented here, the selection of the participating citizens of Rimbach was not based on random assignment, but on self-selection. We can assume that the subjects, especially the adults, had informed themselves about the issue of cell tower radiation. However, because it is impossible to consciously regulate these levels, this self-selection should not make any difference in this study.
Especially in children below age ten, it is not thought possible to maintain a chronic state of anxiety for one and a half years due to an abstract term such as cell tower radiation.

This study limits itself to the following type of questions: "Did the level of a given substance predominantly increase or decrease during the study period?" Independent of each model, this question can be clearly answered with the Wilcoxon test and the indication of the confidence interval. The corresponding results are statistically very well supported. Any statements beyond this—e.g. the dependence of levels on certain parameters—cannot be made because with 60 study subjects the number of cases is too small to establish the same type of statistical significance.

The great advantage of the "Rimbach data" is that prior to January 2004 the exposure levels were very low because there was no cell phone tower and because only a few citizens had installed DECT, Wi-Fi and similar devices. In addition, due to the testing equipment with a measurement accuracy of less than ± 3 dB combined with repeated control measurements, the classification of the exposure groups can be considered to be verified.

For the stress hormones adrenaline and noradrenaline, the increase occurred only after the installation and activation of the transmitter, and thereafter, levels continued to decrease but did not fully normalize.
For dopamine, significant differences in the dose-response relationship according to exposure group could be shown after the activation of the new cell tower antenna. Also, the consistently decreasing levels of the hypothetically superordinate regulatory PEA do not support the hypothesis that the stress factor for the observed changes in the adrenergic system would exclusively be found in the realm of psychological factors.

Mode of Action of Microwave Radiation

There is a wide range of evidence to interpret the newly emerging microwave exposures as an invisible stressor.

Microwaves are absorbed by living tissue. The frequencies used for cell phone technologies have a half-life penetration depth of several centimeters, whereby cell membranes constitute no obstacle (35).

Microwaves cause enzymes to malfunction directly by, for example, monomerization (36). Thus, it is conceivable that enzymes of the catecholamine system could be affected directly.

Intracellular processes are changed, and cellular mitosis is disturbed by forces acting on the cellular spindle apparatus (37, 38). The human body is required to provide a higher level of repair services that is comparable to a chronic state of stress. A decrease in adenosine triphosphate (ATP) due to microwave exposure could be demonstrated by Sanders in intracerebral tissue already in 1980 (39).

Within current exposure limits, Friedman could show the stress caused by microwaves in the cell membranes of a cell model (40). The oxygen radicals formed by NADH have an activating effect on subsequent intracellular cascades that amplify the membrane effect by a factor of 10^7, which in turn substantially change intracellular processes (17). Even reproductive impairments due to microwaves are mediated by the formation of free radicals (41).

In industry, more and more microwave devices are being used for chemical peptoid syntheses, which allow for a 100 times faster and more precise production even without any measurable heating (42). The toxic effects of free radicals formed by microwaves are used in such technical applications as water purification (43).

In several studies, the chronic symptoms of residents near cell tower antennas were described (44-48). Interestingly, the expansion of wireless networks corresponds with the increase in prescription expenses for methylphenidate, a drug whose chemical structure is related to PEA and which is indicated in cases of attention deficit disorder (ADD) (49).

Long-term studies over five years suggested an increased cancer incidence due to microwave exposure (50, 51). Since the catecholamine system is directly linked with the nervous system within the psychoneuroimmunological framework beside its organ-specific effects, the observed increase in cancer incidence can now also be understood from a pathophysiological perspective (6, 15, 52, 53).

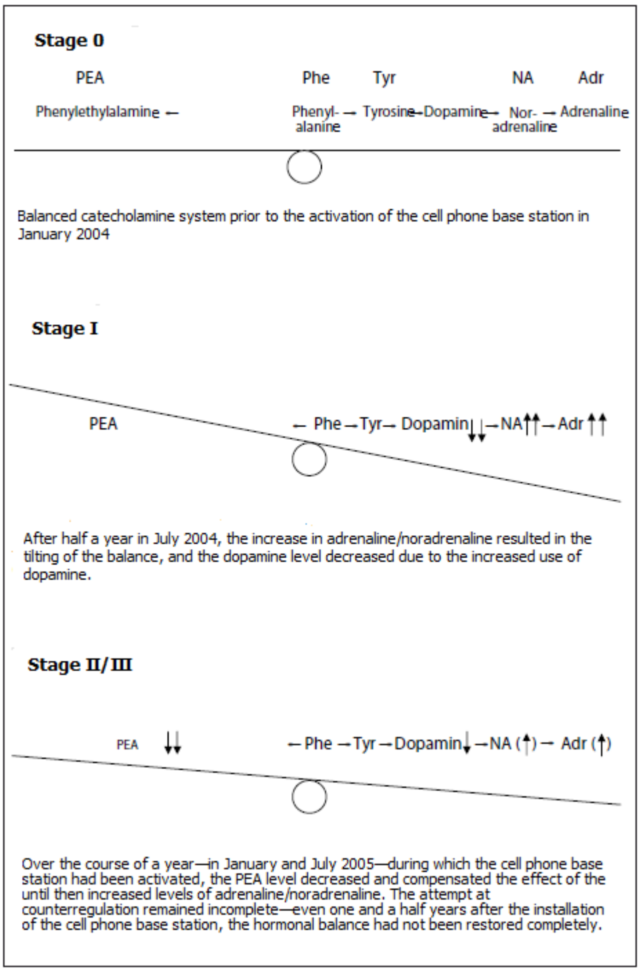


Fig. 17: Stage-like course of the stress response in Rimbach

Hypothesis of the Course of the Stress Response in Rimbach

Significant research on the stress-response axis was carried out in the 1950s. Selye established the nowadays generally accepted theory of the general adaptation syndrome of the human body to a stressor (16). He distinguished between three stages in the stress response, which can be found again in the description of the microwave syndrome according to Hecht (2, 3). Thus, after the stages of alarm and resistance, the last stage of exhaustion sets in (Fig. 17). The parameters investigated in the Rimbach study follow this pattern.

STAGE I—Activation Stage
The results of the long-term study presented here show an immediate activation of the adrenergic system. After the activation of the cell phone base station under investigation, the parameters adrenaline and noradrenaline increase significantly within a period of one and a half years. Because of the increased production of the final hormones noradrenaline/adrenaline, the use of dopamine increases, and as a result, the dopamine level decreases. The decrease in the dopamine level is the more pronounced, the higher the GSM radiation exposure level is at the residence of the individual participants.

STAGE II—Adaptation Stage
After this sympathicotonic activation stage, the body tries to compensate the increase in adrenaline and noradrenaline. In order to inhibit the overshooting catecholamine production and to ensure a stable regulation, the phenylethylamine level (PEA level) decreases. Here the decrease in PEA starts in the highest exposure group first.

STAGE III—Premorbid Stage
According to our hypothesis, the effects of adrenaline and noradrenaline are inhibited by feedback mechanisms at the expense of a chronically, over six continuous months, lowered PEA level. However, the attempt at counterregulation remains incomplete—even one and a half years after the installation of the cell phone base station; the hormonal balance had not been restored completely. The PEA level remains at a low level, which is to be interpreted as evidence for the beginning of exhaustion.

Conclusion

Thus, the following hypothesis is proposed: Although participants maintained their usual lifestyle, they developed chronic stress with a primary increase in adrenaline/noradrenaline and a subsequent decrease in dopamine in response to the microwave exposure from the newly installed cell phone base station. During the stage of counterregulation, the "trace amine" PEA decreases and remains decreased.
This is of considerable clinical relevance because psychiatric symptoms also exhibit altered PEA levels. In Rimbach, the increase in sleep problems, cephalgia, vertigo, concentration problems, and allergies could be clinically documented after the cell phone base station had been activated. The newly developed symptoms can be explained clinically with the help of disturbances in the humoral stress axis (53).

After having exhausted the biological feedback mechanisms, major health problems are to be expected. The possible long-term consequences of remaining caught in the exhaustion stage have already been described by Hecht and Selye (3, 16).

Thus, the significant results presented here not only provide clear evidence for health-relevant effects in the study subjects of Rimbach after a new GSM base station had been installed there, but they also offer the opportunity to carry out a causal analysis. This has already been successfully done in the "shut-down study" of Schwarzenburg, Switzerland (54). In Rimbach, the documented levels should return to normal once the relevant base station is shut down.

Epidemiological Evidence

There is current epidemiological evidence for the considerable clinical relevance of the dysfunction of the humoral stress axis with its endpoints of PEA decrease and adrenaline increase, as documented by us.

1. Decreased PEA levels can be found in a large portion of ADD/ADHD patients. As therapy methylphenidate is used, a substance that is structurally related to PEA. Between 1990 and 2004, the boom time of cell phones, prescription costs for this medication had increased by a factor of 86 (49, 55).

2. As part of the German Mobile Telecommunication Research Programme, approximately 3000 children and adolescents were studied in Bavaria for their individual cell phone radiation exposure levels in relation to health problems. Among the various data sets, the data set regarding behavioral problems showed a significant increased risk for both adolescents (OR: 3.7, 95%-CI: 1.6-8.4) and also children (OR: 2.9, 95%-CI: 1.4-5.9) in the highest exposure group (56). For the first time, the "Rimbach Study" provides a model of explanation in biochemical terms.

3. Pheochromocytomata are adrenaline- and noradrenaline-secreting tumors of the adrenal gland (57). This type of tumor due to microwave exposure has already been demonstrated in animal experiments in 1985 (5). The increase of this disease in the US population is highly significant. Concurrent with the increase in local microwave exposures due to an increased number of base stations and use of wireless communication technologies, the number of cases have increased from 1,927 to 3,344 between 1997 and 2006 (58, 59).

It is a physician's responsibility—not bound by directives—to work toward the preservation of the natural basis of life regarding human health (60). Now it is the duty of the responsible agencies (public health department, Bavarian State Ministry of the Environment and Public Health as well as other federal ministries) to investigate the current situation.

Note
For the data collection, financial and personnel support was provided by INUS Medical Center and the two laboratories Lab4more GmbH and Neuroscience Inc.
The above-listed institutions were so kind to provide clinical examinations as well as the laboratory tests for the evaluation without external funding.

Acknowledgement
Many thanks to the Rimbach participants as well as the staff of the supportive clinics and laboratories, without whose efforts this study would not have been carried out. For the deciphering of cryptic handwriting, we owe Christina Panchyrz our gratitude.

Contact:

Professor Dr. rer. nat. Dr. habil. Klaus Buchner
Straßbergerstraße 16
80809 München

Dr. med. Horst Eger (Korrespondenz)
Ärztlicher Qualitätszirkel „Elektromagnetische Felder in der Medizin - Diagnostik, Therapie, Umwelt'; (Code-Nr. 65143 KV Bayern)
Marktplatz 16
95119 Naila
E-mail: horst.eger@arcormail.de

Editor's Note

The above paper is identified as an original scientific paper and it was subject to a special peer-review process in cooperation with the Scientific Advisory Board.

The Editorial Team

Translation
By Katharina Gustavs and authorized by the authors and publisher
Original publication: BUCHNER K, EGER H. (2011): Veränderung klinisch bedeutsamer Neurotransmitter unter dem Einfluss modulierter hochfrequenter Felder - Eine Langzeiterhebung unter lebensnahen Bedingungen (Wissenschaftlicher Originalbeitrag). Umwelt-Medizin-Gesellschaft 24(1): 44-57.

(Submitted: 9 July 2010)
(Revised version accepted: 13 December 2010)

Literature

(1) STRAHLENSCHUTZKOMMISSION (2003): Forschungsbedarf im Sonderforschungsprogramm Mobilfunk, 3./04.07.2003.

(2) HECHT, K. (2001): Auswirkungen von Elektromagnetischen Feldern - Eine Recherche russischer Studienergebnisse 1960-1996, [Erhebung im Auftrag des Bundesinstituts für Telekommunikation (Auftrag Nr. 4231/630402)], umwelt-medizin-gesellschaft 14(3): 222-231.

(3) HECHT, K., SAVOLEY, E. N. (2007): Überlastung der Städte mit Sendeanlagen - eine Gefahr für die Gesundheit der Menschen und eine Störung der Ökoethik International Research Centre of Healthy and Ecological Technology, Berlin.

(4) BECKER, R. O. (1990): Cross Currents, J. P. Tarcher, Los Angeles.

(5) GUY, A. W., CHOU, C. K., KUNZ, L. L.,CROWLEY, J., KRUPP, J. (1985): Effects of long-term low-level radiofrequency radiation exposure on rats, summary, august 1985, Prepared for USAF SCHOOL OF AEROSPACE MEDECINE, Seattle, USAFSAM-TR-85-64, contract number F33615-80-C-0612, 9: 1-20.

(6) SCHMIDT, R. F., THEWS, G. (1983): Physiologie des Menschen, 21. Auflage, Springer Verlag, Berlin: 124

(7) BUNDESNETZAGENTUR (2004): STANDORTBESCHEINIGUNG Nr. 680 894 vom 5. 4 2004

(8) THOMAS, L. (1992): Labor und Diagnose, 4. Auflage, Die Medizinische Verlagsgesellschaft, Marburg.

(9) LABOR DIAGNOSTIKA Nord GmbH & Co. KG (Hrsg) (2008): Instructions For Use 3-Cat ELISA, [http://www.ldn.de/index.php/Catecholamines-ELISA/View-all-products.html, letzter Zugriff: 11.11.2010].

(10) BIEGER, W. P. (2004): Neuroscience - Grundlagen, Diagnostik und Therapie von Neurotransmitter-vermittelten Erkrankungen, [http://dr-bieger.de/neurostress-aktuallisierte-kurzuebersicht/#0, letzter Zugriff: 08.06.2010].

(11) HUISMANN, H., WYNVEEN, P., SETTER, P. W. (2009): Studies on the immune response and preparation of antibodies against a large panel of conjugated neurotransmitters and biogenic amines: specific polyclonal antibody response and tolerance, Journal of Neurochemistry, 10.1111/j.1471-4159.2009.06492.x.

(12) BÜNING, H., TRENKLER, G. (1978): Nichtparametrische statistische Methoden, W. de Gruyter, Berlin, New York.

(13) BOSCH, K. (2005): Elementare Einführung in die angewandte Statistik, vieweg studium, Wiesbaden.

(14) INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION - ICNIRP (1998): Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz). Health Physics 74 (4): 494-522; 1998. [http://www.icnirp.org/PubMost.htm, letzter Zugriff 11.11.2010].

(15) LÖFFLER, G., PETRIDES, P. (1997): Biochemie und Pathochemie, 6. Auflage, Springer Verlag, Berlin: 800-821.

(16) SELYE, H. (1953): Einführung in die Lehre von Adaptations-Syndrom, Thieme Verlag, Stuttgart.

(17) LINDER, H. (2005): Biologie, 22. Auflage, Schroedelverlag, Braunschweig: 155

(18) BARGER, A., DALE, H. (1910): Chemical structure and sympathomimetic action of amines, J. Physiol. (Lond.) 41: 19-59.

(19) BURCHETT, S. A., HICKS, T. P. (2006): The mysterious trace amines: Protean neuromodulators of synaptic transmission in mammalian brain, Progress in Neurobiology 79: 223-246.

(20) LINDEMANN, L., HOENER, M. (2005): A renaissance in trace amines inspired by a novel GPCR family, TRENDS in Pharmacological Sciences 26(5): 274-281.

(21) BERRY, M. D. (2004): Mammalian central nervous system trace amines Pharmacologic amphetamines, physiologic neuromodulators, J. Neurochem. 90: 257-271.

(22) XIE, Z., MILLER, G. M. (2008): ß-Phenylethylamine Alters Monoamine Transporter Function via Trace Amine-Associated Receptor 1: Implication for Modulatory Roles of Trace Amines in Brain, The journal of pharmacology and experimental therapeutics 325: 617-628.

(23) ZELLER, E. A., MOSNAIM, A. D, BORISON, R. L, HUPRIKAR S. V. (1976): Phenylethylamine: Studies on the Mechanism of Its Physiological Action, Advances in Biochemical Psychopharmacology 15: 75-86.

(24) ORREGO, H. (1976): pers. Mitteilung, in: ZELLER, E. A., MOSNAIM, A. D, BORISON, R. L, HUPRIKAR S. V. (1976): Phenylethylamine: Studies on the Mechanism of Its Physiological Action, Advances in Biochemical Psychopharmacology 15: 83.

(25) BOULTON, A. (1976): Identification, Distribution, Metabolism, and Function of Meta and Para-Tyramine, Phenylethylamine and Tryptamine in Brain, Advances in Biochemical Psychopharmacology 15: 57-67.

(26) BERRY, M. D. ET AL. (1994): The effects of administration of monoamine oxidase-B inhibitors on rat striatal neurone responses to dopamine, Br. J. Pharmacol. 113: 1159-1166.

(27) RAO, T. S., BAKER, G. B., COUTTS, R. T. (1987): N-(3-Chloropropyl) Phenylethylamine as a possible Prodrug of ß-Phenylethylamine: Studies in the rat brain, Progress in neuro-psychopharmacology & biological psychiatry 11: 301 -308.

(28) SABELLI, H. C., MOSNAIM, A. D. (1974): Phenylethylamine hypothesis of affective behavior, Am. J. Psychiatry 131: 695-699.

(29) SABELLI, H. C. (1995): Phenylethylamine modulation of affect, Journal of neuropsychiatry and clinical neurosciences 7: 6-14.

(30) BIRKMAYER, W., RIEDERER, P., LINAUER W., KNOLL, J. (1984): The antidepressive efficacy of l-deprenyl, Journal of Neural Transmission 59: 81-7.

(31) DAVIS, B. A., BOULTON, A. A. (1994): The trace amines and their acidic metabolites in depression - an overview, Prog. Neuropsychopharmacol. Biol. Psychiatry 18: 17-45.

(32) SABELLI, H., FINK, P., FAWCETT. J., TOM, C. (1996): Sustained Antidepressant Effect of PEA Replacement, The journal of neuropsychiatry and clinical neurosciences 8: 168-171.

(33) BAKER, G. B., BORNSTEIN, R. A., ROUGET, A. C., ASHTON, S. E., VAN MUYDEN, J. C., COUTTS, R. T. (1991): Phenylethylaminergic Mechanisms in Attention-Deficit Disorder, Biologic Psychiatry 29: 15-22.

(34) KUSAGA, A., YAMASHITA, Y., KOEDA, T., HIRATANI, M., KANEKO, M., YAMADA, S., MATSUISHI, T. (2002): Increased urine phenylethylamine after methylphenidate treatment in children with ADHD, Annals of neurology, 52(3): 372-4.

(35) SCHLIEPHAKE, E. (1960): Kurzwellentherapie, Stuttgart, Fischer Verlag [mit Zitat aus: Deutsche Medizinische Wochenschrift, Heft 32: 1235 (5. August 1932)].

(36) BARTERI, M. (2005): Structural and kinetic effects of mobile phone microwaves on acetylcholinesterase activity, Biophysical Chemistry 113: 245-253.

(37) SCHMID, E., SCHRADER, T. (2007): Different biological effectiveness of ionizing and non-ionising radiations in mammalian cells, Adv. Radio Sci. 5: 1-4.

(38) SCHRADER, T., SCHMID, E., MÜNTER, K., KLEINE-OSTMANN, T. (2008): Spindle Disturbances in Human-Hamster Hybrid (AL) Cells Induced by Mobile Communication Frequency Range Signals, Bioelectromagnetics 29: 626 - 639.

(39) SANDERS, A. P., SCHAEFER, D. J., JOINES, W. T. (1980): Microwave effects on energy metabolism of rat brain, Bioelectromagnetics 1: 171-182. 42

(40) FRIEDMAN, J., KRAUS, S., HAUPTMAN, Y., SCHIFF, Y., SEGER, R. (2007): Mechanism of a short-term ERK activation by electromagnetic fields at mobile phone frequency, Biochemical Journal 405(Pt 3): 559-568.

(41) DESAI, N. R., KESARI, K. K., AGARWAL, A. (2009): Pathophysiology of cell phone radiation: oxidative stress and carcinogenesis with focus on male reproductive system, Reproductive Biology and Endocrinology 7: 114: 1-9.

(42) OLIVOS, H. J., ALLURI, P. G., REDDY, M. M., SALONY, D., KODADEK, T. (2002): Microwave-Assisted Solid-Phase Synthesis of Peptoids, Organic Letters 4(23): 4057-4059.

(43) HORIKOSHI, S., HIDAKA, H., SERPONE, N. (2003): Hydroxyl radicals in microwave photocatalysis. Enhanced formation of OH radicals probed by ESR techniques in microwave-assisted photocatalysis in aqueous TiO2 dispersions, Chemical Physics Letters 376: 475-48.

(44) SANTINI, R., SANTINI, P., DANZE, J. M., LE RUZ, P., SEIGNE, M. (2002): Symptoms experienced by people living in vicinity of mobile phone base stations: Incidences of distance and sex, Pathol. Biol. 50: 369-373.

(45) NAVARRO, E. A., SEGURA, J., PORTOLES, M., GÖMEZ-PERRETTA DE MATEO, C. (2003): The Microwave Syndrome: A Preliminary Study in Spain, Electromagnetic biology and medicine 22(2 & 3): 161 -169.

EGER, H., JAHN, M. (2010): Spezifische Symptome und Mobilfunkstrahlung in Selbitz (Bayern) - Evidenz für eine Dosiswirkungsbeziehung, umwelt-medizin-gesellschaft 23(2):130-139.

(46) AUGNER, C., HACKER, G.W., OBERFELD, G., FLORIAN, M., HITZL, W., HUTTER, J., PAUSER, G. (2010): Effects of Exposure to GSM Mobile Phone Base Station Signals on Salivary Cortisol, Alpha-Amylase, and Immunoglobulin A., Biomed Environ Sci 23 (3): 199-207.

(47) ABDEL-RASSOUL, G., EL-FATEH, O.A., SALEM, M.A., MICHAEL, A., FARAHAT F., EL-BATANOUNY, M., SALEM, E. (2007): Neurobehavioral effects among inhabitants around mobile phone base stations. NeuroToxicology 28(2): 434-40.

(48) FEGERT, J., GLAESKE, G., JANHSEN, K., LUDOLPH, A., RONGE, C. (2002): Untersuchung zur Arzneimittel-Versorgung von Kindern mit hyperkinetischen Störungen anhand von Leistungsdaten der GKV. Projektbericht für das Bundesministerium für Gesundheit und Soziale Sicherung, [http://www.home.uni-osnabrueck.de/kjanhsen/ unter Bücher, Buchartikel, Projektberichte, letzter Zugriff 11.11.2010].

(49) EGER, H., NEPPE, F. (2009): Krebsinzidenz von Anwohnern im Umkreis einer Mobilfunksendeanlage in Westfalen, Interview-basierte Piloterhebung und Risikoschätzung, umwelt-medizin-gesellschaft 22(1): 55-60.

(50) EGER, H., HAGEN, K. U., LUCAS, B., VOGEL, P., VOIT, H. (2004): Einfluss der räumlichen Nähe von Mobilfunksendeanlagen auf die Krebsinzidenz, umwelt-medizin-gesellschaft 17(4): 326-332.

(51) FELTEN, D. L., MAIDA, M. E. (2002): Psychoneuroimmunology, in: FINK, G. (Hrsg.): Encyclopedia of the Human Brain, Vol. 4, Academic Press, San Diego: 103-127.

(52) STRAUB, R. H. (Hrsg.) (2007): Lehrbuch der klinischen Pathophysiologie komplexer chronischer Erkrankungen, Band 1 und 2, Vandenhoeck und Ruprecht, Göttingen: (2) 89-98.

(53) ABELIN, T., ALTPETER, E., RÖÖSLI, M. (2005): Sleep Disturbances in the Vicinity of the Short-Wave Broadcast Transmitter Schwarzenburg - Schlafstörungen in der Umgebung des Kurzwellensenders Schwarzenburg, Somnologie 9: 203-209.

(54) PAFFRATH, D., SCHWABE, U. (Hrsg.) (2004): Arzneiverordnungs-Report 2004, Aktuelle Daten, Kosten, Trends und Kommentare. Springer-Verlag, Berlin. [http://wido.de/arzneiverordnungs-rep.html unter download, letzter Zugriff 11.11.2010].

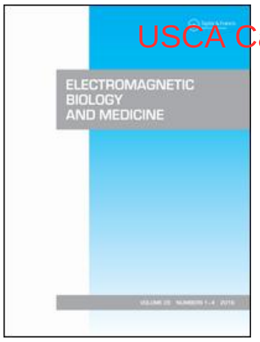
(55) THOMAS, S., HEINRICH, S.,VON KRIES R., RADON K. (2010): Exposure to radiofrequency electromagnetic fields and behavioural problems in Bavarian children and adolescents. Eur J Epidemiol 25(2): 135-141.

(56) SIEGENTHALER, W. K., HORNBOSTEL, H. D. (1984): Lehrbuch der Inneren Medizin, Georg Thieme Verlag, Stuttgart, New York.

(57) MILHAM, S. (2010): Dirty electricity - electrification and the diseases of civilization, universe, Bloomington.

(58) OSSIANDER, E. (2010): persönliche Mitteilung [Numbers of hospitalizations per year for ICD-9 code 227.0 (benign tumor of the adrenal gland, 1987-2007, Epidemiology Office, Washington State Department of Health Pheochromocytoma, ICD 227.0, 1997-2006, US Department of Health and Human Services, H.CUPnet.

Cell Towers - DNA; Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations. Electromagnetic Biology and Medicine. (Zothansiama et al); 2017



Taylor & Francis
Taylor & Francis Group

Electromagnetic Biology and Medicine

ISSN: 1536-8378 (Print) 1536-8386 (Online) Journal homepage: http://www.tandfonline.com/loi/iebm20

Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations

Zothansiama, Mary Zosangzuali, Miriam Lalramdinpuii & Ganesh Chandra Jagetia

To cite this article: Zothansiama, Mary Zosangzuali, Miriam Lalramdinpuii & Ganesh Chandra Jagetia (2017): Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations, Electromagnetic Biology and Medicine, DOI: 10.1080/15368378.2017.1350584

To link to this article: http://dx.doi.org/10.1080/15368378.2017.1350584

Published online: 04 Aug 2017.

ELECTROMAGNETIC BIOLOGY AND MEDICINE
https://doi.org/10.1080/15368378.2017.1350584

Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations

Zothansiama, Mary Zosangzuali, Miriam Lalramdinpuii, and Ganesh Chandra Jagetia

Department of Zoology, Cancer and Radiation Biology Laboratory, Mizoram University, Aizawl, Mizoram, India

ABSTRACT
Radiofrequency radiations (RFRs) emitted by mobile phone base stations have raised concerns on its adverse impact on humans residing in the vicinity of mobile phone base stations. Therefore, the present study was envisaged to evaluate the effect of RFR on the DNA damage and antioxidant status in cultured human peripheral blood lymphocytes (HPBLs) of individuals residing in the vicinity of mobile phone base stations and comparing it with healthy controls. The study groups matched for various demographic data including age, gender, dietary pattern, smoking habit, alcohol consumption, duration of mobile phone use and average daily mobile phone use. The RF power density of the exposed individuals was significantly higher ($p < 0.0001$) when compared to the control group. The HPBLs were cultured and the DNA damage was assessed by cytokinesis blocked micronucleus (MN) assay in the binucleate lymphocytes. The analyses of data from the exposed group ($n = 40$), residing within a perimeter of 80 m of mobile base stations, showed significantly ($p < 0.0001$) higher frequency of micronuclei when compared to the control group, residing 300 m away from the mobile base station/s. The analysis of various antioxidants in the plasma of exposed individuals revealed a significant attrition in glutathione (GSH) concentration ($p < 0.01$), activities of catalase (CAT) ($p < 0.001$) and superoxide dismutase (SOD) ($p < 0.001$) and rise in lipid peroxidation (LOO) when compared to controls. Multiple linear regression analyses revealed a significant association among reduced GSH concentration ($p < 0.05$), CAT ($p < 0.001$) and SOD ($p < 0.001$) activities and elevated MN frequency ($p < 0.001$) and LOO ($p < 0.001$) with increasing RF power density.

ARTICLE HISTORY
Received 27 April 2017
Accepted 30 June 2017

KEYWORDS
Antioxidants; genotoxicity; humans; micronucleus; power density

Introduction

The mobile phone base stations are one of the essential parts of mobile telecommunication as they transmit the signals in the form of radiofrequency radiations (RFRs) that are received by the mobile phones, acting as a two-way radio, i.e. transceiver (Kwan-Hoong, 2005), generally operating in the frequency range of 900 MHz to 1.9 GHz (Levitt and Lai, 2010). The ever-increasing subscription of mobile phones has led to a phenomenal increase in the mobile phone base stations required to cater to the needs of increasing demand of the mobile subscribers. For decades, there has been an increasing concern on the possible adverse effects of RFR on humans living near mobile phone base stations despite the fact that RFR spectrum are of low frequency (ARPANSA, 2011). There has been a link between the RFR exposures and several human health disorders including cancer, diabetes, cardiovascular and neurological diseases (Bortkiewicz et al., 2004; Eger et al., 2004; Havas, 2013; Lerchl et al., 2015; Wolf and Wolf, 2004). The International Agency for Research on Cancer (IARC, 2011) has classified RFR as a possible carcinogen to humans (group 2B), based on the increased risk for glioma, a malignant type of brain cancer associated with wireless phone use (Hardell et al., 2013).

RFR may change the fidelity of DNA as the increased incidence of cancer has been reported among those residing near mobile phone base stations (Abdel-Rassonl et al., 2007; Bortkiewicz et al., 2004; Cherry, 2000; Eger et al., 2004; Hardell et al., 1999; Hutter et al., 2006; Wolf and Wolf, 2004). RFR emitted from mobile base stations is also reported to increase the DNA strand breaks in lymphocytes of mobile phone users and individuals residing in the vicinity of a mobile base station/s (Gandhi and Anita, 2005; Gandhi et al., 2014). Exposure of human fibroblasts and rat granulosa cells to RFR (1800 MHz, SAR 1.2 or 2 W/kg) has been reported to induce DNA single- and double-strands breaks (Diem et al., 2005). Irreversible DNA damage was also reported in cultured human lens epithelial cells exposed to microwave generated by mobile phones (Sun et al., 2006). The adverse health effects of RFR are still debatable as many studies indicated above have found a positive correlation between the DNA

CONTACT Ganesh Chandra Jagetia gc.jagetia@gmail.com Department of Zoology, Mizoram University, Aizawl 796 004, Mizoram, India.

damage and RFR exposure; however, several studies reported no significant effect of RFR on DNA strand breaks and micronuclei formation in different study systems (Li et al., 2001; Tice et al., 2002; McNamee et al., 2003; Maes et al., 2006). The potential genotoxicity of RFR emitted by mobile phone base stations can be determined by micronucleus (MN) assay, which is an effective tool to evaluate the genotoxic or clastogenic effects of physical and chemical agents. This technique has also been used to quantify the frequencies of radiation-induced MN in human peripheral blood lymphocytes (HPBLs) (Fenech and Morley, 1985; Jagetia and Venkatesha, 2005; Prosser et al., 1988; Yildirim et al., 2010).

Besides its effect on DNA damage and association of cancer in individuals living near mobile phone base station, the deep penetration of RFR within the living cells may cause overproduction of free radicals particularly reactive oxygen species (ROS), thereby inducing adverse effects in living cells (Yakymenko et al., 2015). ROS amount is also reported to increase during infections, exercise, exposure to pollutants, UV light, ionizing radiations, etc. (Kunwar and Priyadarsini, 2011). Uncontrolled generations of ROS can lead to their accumulation causing oxidative stress in the cells. Any chronic exposure to conditions that increase the oxidative stress leads to an increased risk of cancer, and elevated levels of cancer have been demonstrated in populations with increased residential exposure to RFR (Dart et al., 2013; IARC, 2011). The change in the activities of antioxidants such as glutathione (GSH), superoxide dismutase (SOD) and catalase (CAT) may be regarded as an indicator of increased oxidative stress (Kerman and Senol, 2012). Since lipid peroxidation (LOO) is a free-radical oxidation product of polysaturated fatty acids, detection and measurement of LOO is the evidence which is frequently cited to support the involvement of free-radical reactions in toxicity and disease progression (Gutteridge, 1995). The increasing use of mobile phones and installation of more mobile base stations stimulated us to obtain an insight into the genotoxic effects of RFR using MN assay and alteration in the antioxidant status in the PBLs of the individuals residing in the vicinity of the mobile phone base stations.

Methods

Chemicals

RPMI-1640 medium, phytohemagglutinin, acridine orange, bovine serum albumin (BSA), GSH reduced, nicotinamide adenosine dinucleotide (NADH), nitrobluetetrazolium (NBT) and *n*-butanol were purchased from HiMedia laboratories Pvt Ltd. (Mumbai, Maharashtra, India). Methanol, acetic acid, Folin–Ciocalteu reagent, potassium tartarate, hydrogen peroxide (H_2O_2), trichloroacetic acid (TCA), hydrochloric acid (HCl) and potassium chloride (KCl) were purchased from MERCK (Mumbai, Maharashtra, India). Cytochalasin B, thiobarbaturic acid (TBA) and phenazinemethosulphate (PMS) were purchased from Sigma Aldrich Chemical Co (Bangalore, Karnataka, India) and 5,5′-dithio-2-nitrobenzoic acid (DTNB) was procured from Tokyo Chemical Industry (Tokyo, Japan).

Power density measurement from mobile phone base stations

Six mobile phone base stations, operating in the frequency range of 900 MHz ($N = 2$) and1800 MHz ($N = 4$), erected in the thickly populated areas of Aizawl city were selected for the present study. Both dish and sectored antennas of each base station are arranged equilaterally that provide 360° network coverage. The power output of all the base stations is 20 W, with their primary beam emitting radiation at an angle of 20°. Power density measurements (using HF-60105V4, Germany) were carried out in the bedroom of each participant where they spent most of the time and hence have the longest constant level of electromagnetic field exposure. Power density measurement was carried out three times (morning, midday and evening), and the average was calculated for each residence around each base station. The main purpose of the measurement of power density was to ensure that RFR emission from each site did not exceed the safe public limits and to determine any difference in power density between selected households that were close to (within 80 m) and far (>300 m) from the mobile phone base stations. The safety limits for public exposure from mobile phone base stations are 0.45 W/m^2 for 900 MHz and 0.92 W/m^2 for 1800 MHz frequency as per Department of Telecommunications, Ministry of Communications, Government of India, New Delhi guidelines (DoT, 2012).

Selection of subjects

The study was carried out in Aizawl city (23°43′37.58′′N and 92°43′3.49′′E), Mizoram, India, during 2015 and 2016. Since the city is located in the hilly region, some residences are located horizontally with the top of the towers from which RFR are emitted, making it possible to get an exposure at a short distance of 1–20 m, despite being erected on the rooftop or in the ground. A minimum of two individuals were sampled from each household and at least five individuals were sampled around each mobile base station. Individuals sampled around each base station were matched for their age and gender (Table 1). The exposed group consisted of 40 healthy

Table 1. Composition of base stations and the demographic characteristics of the exposed group.

	Components				Gender of volunteers	
Base station	Disc antenna	Sectored antenna	Power density (mW/m^2)	Average age (years) of volunteers	Male	Female
1	3	10	3.90–6.52	28.8	3	4
2	6	10	5.12–7.32	30.0	3	3
3	3	9	2.80–6.55	28.2	4	4
4	11	6	3.58–7.52	28.9	2	4
5	6	4	4.56–5.43	28.6	3	2
6	6	4	3.58–6.53	27.6	3	5

individuals who fulfilled the inclusion criteria of being above 18 years of age and residing in the vicinity of mobile phone base stations (within 80 m radius). The control group comprised of 40 healthy individuals matched for age and gender who had been living at least 300 m away from any mobile phone base stations. None of the participants have occupational exposure to RFR, and there were no electric transformer, high tension electric power line and radio and television transmitters close to (at least 500 m) their residences. Sampling was also done only from those residences who did not use microwave oven for cooking, Wifi devices and any other major source of electromagnetic field as they are known to cause adverse effects (Atasoy et al., 2013; Avendaño et al., 2012). The study was approved by the Human Ethics Committee, Mizoram University, Aizawl, India, and only those individuals who gave their voluntary written consent were included in the study.

Questionnaire used

A questionnaire was prepared to collect information on demographic data such as family and exposure histories, lifestyle such as smoking habit (≤10 cigarette in a day), alcohol consumption (three to four times a week) and dietary pattern, duration of stay near mobile phone base stations, duration of mobile phone use and average daily mobile phone use.

Blood sample collection and lymphocyte culture

The blood samples were collected by venipuncture from each volunteer of both groups in individual heparinized tubes. The lymphocyte culture was carried out according to the method described earlier (Jagetia et al., 2001). Briefly, the blood was allowed to sediment and the buffy coat containing nucleated cells was collected in individual sterile glass tubes. Usually 10^6 nucleated cells were inoculated into sterile glass tubes containing RPMI-1640 medium, supplemented with 10% fetal calf serum and phytohemagglutinin as the mitogen. The cells were allowed to grow for the next 44 h and cytochalasin B was added at a final concentration of 5 μg/ml to block the cytokinesis (Fenech and Morley, 1985). The cells were harvested at the end of 72 h after initiation of lymphocyte culture by centrifugation. The cell pellet was subjected to mild hypotonic treatment so as to retain the cell membrane and fixed in freshly prepared Carnoy's fixative (methanol: acetic acid, 3:1). The cell suspension was dropped onto precleaned coded slides to avoid observer's bias and stained with acridine orange. Usually a total of 1000 binucleate cells (BNCs) with well-preserved cytoplasm were scored from each individual using a fluorescence microscope (DM 2500, Leica MikrosystemeVertrieb GmbH, Wetzlar, Germany). Scoring of MN frequencies was performed based on the criteria of Fenech et al. (2003).

Biochemical estimations

The antioxidants were measured in the plasma of the study groups. Protein contents were measured by the method of Lowry et al. (1951) using BSA as the standard.

Glutathione

GSH contents were measured using the method given by Moron et al. (1979). Briefly, 80 μl of plasma was mixed with 900 μl of 0.02 M sodium phosphate buffer and 20 μl of 10 mM DTNB and incubated for 2 min at room temperature. The absorbance of the sample was read against blank at 412 nm in a UV-Visible spectrophotometer (SW 3.5.1.0. Biospectrometer, Eppendorf India Ltd., Chennai), and the GSH concentration was calculated from the standard curve and expressed in μmol/mg protein.

Superoxide dismutase

The SOD activity was measured by the method of Fried (1975). Briefly, 100 μl each of plasma and 186 μM PMS were mixed with 300 μl of 3 mM NBT and 200 μl of 780 μM NADH. The mixture was incubated for 90 s at 30°C and 1 ml of acetic acid and 4 ml of *n*-butanol were added to stop the reaction. The blank consisted of all the reagents, and distilled H_2O was added instead of plasma. The absorbance of test and blank was measured at 560 nm using a UV-VIS spectrophotometer, and the

enzyme activity has been expressed in units (1U = 50% inhibition of NBT reduction)/mg protein.

$$\% \text{ inhibition} = (\text{OD of blank} - \text{OD of test/OD of blank}) \times 100$$
$$\text{SOD unit} = 1/50 \times \% \text{ inhibition.}$$

Catalase

The CAT activity was determined using the modified protocol of Aebi (1984). Briefly, 200 µl of 3% H_2O_2 was mixed with 50 µl each of plasma and 150 µl of 50 mM phosphate buffer (pH 7.0). The absorbance was recorded at 240 nm in a UV-VIS spectrophotometer. The decomposition of H_2O_2 can be followed directly by the decrease in absorbance. The enzyme activity has been expressed in units/mg protein. The catalytic activity of CAT at a time interval of 15 s was calculated by the following formula,

$$K = 0.153\,(\log A_0/A_1)$$

where A_0 is the absorbance at 0 s and A_1 is the absorbance at 15 s.

Lipid peroxidation

The LOO was estimated by the method of Beuege and Aust (1978). Briefly, plasma was mixed with 10% TCA, 0.8% TBA and 0.025 N HCl in a 1:2 ratio. The mixture was boiled for 10 min in a boiling water bath. After centrifugation, the absorbance of the supernatant was recorded at 540 nm UV-VIS spectrophotometer.

Statistical analyses

The data are expressed as mean ± standard error of the mean. Student's "t" and Chi-square tests were used for comparison of demographic variables of the exposed and control groups. Pearson`s correlation analysis was performed to determine the relationship between power density and the distance of residences from the base stations. Mann Whitney U test was applied to determine the significance between the control and exposed group for MN frequencies. Student's "t" test was performed to determine the significance between the groups for antioxidants. Multiple linear regression analyses were carried out for the prediction of MN frequency and antioxidants status separately from the demographic characteristics. SPSS Ver.16.0 software (SPSS Inc, Chicago, IL, USA) was used for statistical analyses. A p-value of less than 0.05 was considered statistically significant.

Results

The demographic characteristics of both exposed and control groups are depicted in Table 2. The groups matched for most of the demographic data such as age, gender, dietary pattern, smoking habit, alcohol consumption, mobile phone usage, duration of mobile phone use and average daily mobile phone use (Table 2). A highly significant variation (p < 0.0001) was observed for the distance of household from the base station (40.10 ± 3.02 vs. 403.17 ± 7.98 in m) between exposed and control groups. The data of RF

Table 2. Demographic data of the exposed and control groups.

		Exposed group		Control group			p-value
Characteristics	Category	N (%)	M±SEM	N (%)	M±SEM	t/χ^2-value	(t/χ^2-value)
Age (years)	20–30	26 (65)	28.6 ± 0.85	29 (72.5)	28.6 ± 0.85	1.074/–	0.286/–
	31–40	14 (35)		11 (27.5)			
Gender	Male	18 (45)		21 (52.5)		–/0.450	–/0.502
	Female	22 (55)		19 (47.5)			
Diet	Vegetarian	5 (12.5)		7 (17.5)		–/0.392	–/0.531
	Nonvegetarian	35 (87.5)		33 (82.5)			
Smoking habit	Yes	16 (40)		14 (35)		–/0.213	–/0.644
	No	24 (60)		26 (65)			
Alcohol consumption	Yes	7 (17.5)		9 (22.5)		–/0.312	–/0.576
	No	33 (82.5)		31 (77.5)			
Mobile phone usage	User	37 (92.5)		35 (87.5)		–/0.556	–/0.456
	Nonuser	3 (7.5)		5 (12.5)			
Duration of mobile phone use (years)	≤5	9 (24.32)	6.32 ± 0.265	11 (31.42)	5.91 ± 0.296	1.032/–	0.306/–
	>5	28 (75.68)		24 (68.58)			
Daily mobile phone use (hours)	≤3	24 (64.86)	3.054 ± 0.229	25 (71.42)	2.800 ± 0.156	1.145/–	0.256/–
	>3	13 (35.13)		10 (28.58)			
Distance from the base station (m)	1–20	8 (20)	40.10 ± 3.02		403.17 ± 7.98	42.046/–	0.0001/–
	21–40	12 (30)					
	41–60	13 (32.5)					
	61–80	7 (17.5)					
Power density (mW/m^2)	Range	2.80–7.52	5.002 ± 0.182	0.014–0.065	0.035 ± 0.002	27.247/–	0.0001/–
Duration of residing near the base station (years)	5–10	33 (82.5)	7.85 ± 0.419	–	–	–	–
	11–15	7 (17.5)					

power density were collected from 23 houses, each of the exposed group staying within a perimeter of 80 m and those of control group staying at least 300 m away from mobile phone base stations. The RF power density of the exposed group (2.80–7.52 mW/m^2; average 5.002 ± 0.182 mW/m^2) was significantly higher ($p < 0.0001$) when compared to the control group (0.014–0.065 mW/m^2; average 0.035 ± 0.002 mW/m^2). The highest power density was recorded at a distance of 1–20 m (6.44 ± 0.31 mW/m^2), which is significantly higher ($p < 0.0001$) than those at a distance of 21–40 m (4.79 ± 0.33), 41–60 m (4.48 ± 0.22) and 61–80 m (4.61 ± 0.10). No significant variation was observed for the RFR power density among the distance ranges of 21–40 m, 41–60 m and 61–80 m (Table 1). Nevertheless, there was a highly significant negative correlation between distance from the base station and the power density ($r = -0.509$, $p < 0.0001$).

The MN frequency and LOO were significantly ($p < 0.0001$ for MN and LOO) higher in the exposed group as compared to that of control group, while antioxidants were significantly ($p < 0.01$ for GSH; $p < 0.001$ for CAT and SOD) lower for the exposed group compared to controls irrespective of their demographic characteristics (Tables 3 and 4). On consideration of the demographic characteristics, smokers had significantly higher MN frequency ($p < 0.001$) and LOO ($p < 0.01$) and significantly lower GSH ($p < 0.01$) and SOD ($p < 0.01$) than nonsmokers within each study group. Similarly, alcoholics compared to nonalcoholics had significantly higher MN frequency ($p < 0.01$) and significantly lower GSH ($p < 0.01$) within the exposed group and significantly higher MN frequency ($p < 0.001$) and LOO ($p < 0.01$) within the control group. The smokers of the exposed group had significantly higher MN frequency ($p < 0.001$) and LOO ($p < 0.01$) and significantly lower CAT ($p < 0.001$) and SOD ($p < 0.05$) activities than the smokers of control group. Alcoholic among exposed group also had significantly higher MN frequency ($p < 0.05$) and significantly lower GSH ($p < 0.05$) concentration and CAT ($p < 0.01$) and SOD ($p < 0.05$) activities than the alcoholic of control group. MN frequency and antioxidant status with LOO showed no significant variations between the ages, genders and dietary pattern within the exposed group. Among controls, males compared to females had significantly ($p < 0.05$) higher MN frequency (Table 3).

There was no significant variation in the MN frequency and antioxidant status between mobile phone user and nonuser of exposed group, while individuals who have been using mobile phone for more than 5 years had significantly higher MN frequency ($p < 0.01$) and lower GSH ($p < 0.05$) than those using for less than 5 years. Similarly, exposed group with average daily mobile phone use of above 3 h showed a higher MN frequency ($p < 0.05$) than those having the average daily use of less than 3 h (Table 4). Among the control group, features of mobile phone usage showed no variation in MN frequency and antioxidant status. Significantly lower levels of antioxidants ($p < 0.05$ for GSH; $p < 0.001$ for CAT; $p < 0.01$ for SOD) and higher

Table 3. Function of the demographic characteristics on MN frequencies and the antioxidant status of exposed and control groups.

	Characteristics	Category	*N*	GSH (M±SEM)	CAT (M±SEM)	SOD (M±SEM)	LOO (M±SEM)	MN/1000 BNC (M±SEM)
EXPOSED GROUP	Age (years)	20–30	26	4.604 ± 2.68**	0.022 ± 0.001***	1.832 ± 0.11***	0.646 ± 0.064***	38.15 ± 1.65**
		31–40	14	3.882 ± 2.09	0.021 ± 0.001***	1.791 ± 0.11**	0.755 ± 0.101*	43.71 ± 2.64**
		Total	40	4.351 ± 1.95**	0.021 ± 0.001***	1.823 ± 0.08***	0.677 ± 0.054***	40.10 ± 1.46***
	Gender	Male	18	4.209 ± 3.08*	0.020 ± 0.001***	1.802 ± 0.12**	0.667 ± 0.072**	40.77 ± 2.71*
		Female	22	4.467 ± 2.54	0.023 ± 0.001***	1.834 ± 0.11***	0.686 ± 0.080**	39.54 ± 1.51***
	Dietary pattern	Vegetarian	5	4.360 ± 4.26*	0.019 ± 0.001**	1.913 ± 0.18**	0.650 ± 0.040***	40.20 ± 2.87***
		Nonvegetarian	35	4.350 ± 2.17*	0.022 ± 0.001***	1.807 ± 0.09***	0.682 ± 0.053***	40.08 ± 1.63***
	Smoking habit	Yes	16	3.713 ± 2.28[a]	0.022 ± 0.001***	1.645 ± 0.11*	0.892 ± 0.102[a]**	46.50 ± 1.65[a]***
		No	24	4.777 ± 2.56**	0.021 ± 0.001***	1.932 ± 0.11***	0.535 ± 0.039**	35.83 ± 1.69***
	Alcohol consumption	Yes	7	3.394 ± 2.35[a]*	0.021 ± 0.001**	1.792 ± 0.22*	0.683 ± 0.119	49.71 ± 3.12[a]*
		No	33	4.554 ± 2.16*	0.022 ± 0.001***	1.823 ± 0.08***	0.676 ± 0.061**	38.27 ± 1.47***
CONTROL GROUP	Age (years)	20–30	29	5.380 ± 1.54	0.038 ± 0.001	2.534 ± 0.09	0.389 ± 0.037	31.89 ± 1.64
		31–40	11	4.023 ± 3.82	0.036 ± 0,002	2.492 ± 0.21	0.482 ± 0.062	35.09 ± 1.96
		Total	40	5.007 ± 1.79	0.037 ± 0.001	2.526 ± 0.09	0.415 ± 0.032	32.77 ± 1.31
	Gender	Male	21	5.067 ± 2.70	0.038 ± 0.002	2.434 ± 0.11	0.385 ± 0.049	35.23 ± 1.99[a]
		Female	19	4.940 ± 2.38	0.037 ± 0.001	2.622 ± 0.14	0.447 ± 0.040	30.05 ± 1.49
	Dietary pattern	Vegetarian	7	5.473 ± 2.53	0.039 ± 0.003	2.845 ± 0.17	0.378 ± 0.066	29.85 ± 1.95
		Nonvegetarian	33	4.908 ± 1.08	0.037 ± 0.001	2.453 ± 0.10	0.423 ± 0.038	33.39 ± 1.52
	Smoking habit	Yes	14	3.996 ± 2.66[a]	0.036 ± 0.002	2.181 ± 0.17[a]	0.522 ± 0.055[a]	39.78 ± 1.70[a]
		No	26	5.551 ± 1.53	0.040 ± 0.001	2.717 ± 0.08	0.356 ± 0.036	29.00 ± 1.30
	Alcohol consumption	Yes	9	4.416 ± 2.91	0.036 ± 0.002	2.212 ± 0.23	0.546 ± 0.073[a]	42.44 ± 2.29[a]
		No	31	5.178 ± 2.07	0.038 ± 0.001	2.616 ± 0.09	0.376 ± 0.033	29.96 ± 1.15

*Significant ($p \le 0.05$) between the exposed and control groups.
**Highly significant ($p \le 0.01$) between the exposed and control groups.
***Very highly significant ($p \le 0.001$) between the exposed and control groups.
[a]Significant ($p \le 0.05$) along the demographic characteristics within group.

Table 4. Function of mobile phone usage and residence near base stations on MN frequencies and antioxidants status on exposed and control groups.

	Characteristics	Category	*N*	GSH (M±SEM)	CAT (M±SEM)	SOD (M±SEM)	LOO (M±SEM)	MN/1000 BNC (M±SEM)
EXPOSED GROUP	Mobile phone usage	User	37	4.336 ± 2.07**	0.020 ± 0.002***	1.852 ± 0.08***	0.66 ± 0.051***	40.21 ± 1.55***
		Nonuser	3	4.534 ± 6.04	0.022 ± 0.001***	1.394 ± 0.10*	0.890 ± 0.205*	38.66± 1.37**
	Duration of mobile phone use (years)	≤5	9	5.006 ± 3.26[a]	0.023 ± 0.002**	1.834 ± 0.23**	0.673 ± 0.109*	34.77 ±3.23[a]
		>5	28	4.145 ± 2.24**	0.021 ± 0.001***	1.863 ± 0.08***	0.656 ± 0.058**	41.96 ±1.66***
	Daily mobile phone use (hours)	≤3	24	4.410 ± 1.26*	0.023 ± 0.001***	1.902 ± 0.11***	0.653 ± 0.068**	37.87 ±1.99[a*]
		>3	13	4.233 ± 1.73*	0.020 ± 0.001***	1.765 ± 0.13***	0.674 ± 0.073**	44.53 ±2.02***
	Distance from the base station (m)	1–20	8	3.884 ± 2.20**	0.018 ± 0.002***	1.654 ± 0.18***	0.720 ± 0.154**	43.00 ± 3.94**
		21–40	12	4.174 ± 3.72*	0.020 ± 0.001***	1.762 ± 0.13***	0.674 ± 0.106**	41.69 ± 2.49**
		41–60	13	4.692 ± 3.23	0.022 ± 0.001***	1.903 ± 0.15**	0.600 ± 0.069*	39.00 ± 1.24*
		61–80	7	4.631 ± 6.44	0.025 ± 0.002**	2.016 ± 0.17*	0.494 ± 0.084	36.71 ± 2.57
	Duration of residence near the base station (years)	5–10	33	4.406 ± 2.25*	0.024 ± 0.001***	1.872 ± 0.08**	0.642 ± 0.055***	40.03 ± 3.13**
		11–15	7	4.092 ± 2.54*	0.021 ± 0.001***	1.814 ± 0.12**	0.781 ± 0.170***	40.42 ± 1.66**
	Power density (mW/m^2)	≤4 mW/m^2	7	4.554 ± 2.22*	0.025 ± 0.002**	1.915 ± 0.16*	0.660 ± 0.122**	39.14 ±0.21*
		>4 mW/m^2	33	4.308 ± 2.32**	0.021 ± 0.001***	1.807 ± 0.09***	0.681 ± 0.061***	40.30 ± 1.59***
CONTROL GROUP	Mobile phone usage	User	35	5.145 ± 1.86	0.037 ± 0.001	2.550 ± 0.09	0.417 ± 0.035	32.28 ± 1.40
		Nonuser	5	4.038 ± 4.21	0.041 ± 0.004	2.282 ± 0.25	0.456 ± 0.022	31.80± 1.22
	Duration of mobile phone use (years)	≤5	11	5.528 ± 2.24	0.036 ± 0.003	2.553 ± 0.10	0.372 ± 0.062	31.09 ± 1.88
		>5	24	5.039 ± 2.31	0.037 ± 0.001	2.568 ± 0.13	0.438 ± 0.043	32.83 ± 1.87
	Daily mobile phone use (hours)	≤3	25	5.258 ± 1.99	0.038 ± 0.001	2.524 ± 0.11	0.436 ± 0.041	30.10± 2.46
		>3	10	5.027 ± 3.75	0.036 ± 0.001	2.655 ± 0.19	0.371 ± 0.070	33.16 ± 1.70

*Significant ($p \leq 0.05$) between the exposed and control groups.
**Highly significant ($p \leq 0.01$) between the exposed and control groups.
***Very highly significant ($p \leq 0.001$) between the exposed and control groups.
[a]Significant ($p \leq 0.05$) along the demographic characteristics within group.

MN frequency ($p < 0.001$) and LOO ($p < 0.001$) were observed in the exposed group residing in the vicinity of the base stations for 5–10 years and 11–15 years when compared to the control group. None of the parameters showed a significant variation among the exposed group residing for 5–10 years and 11–15 years in the vicinity of the base stations (Table 4).

As a function of distance from the base stations, MN frequency and LOO within the distance of 1–20 m ($p < 0.01$ for MN and LOO), 21–40 m ($p < 0.01$ for MN and LOO) and 41–60 m ($p < 0.05$ for MN and LOO) were significantly higher in the exposed group than that of the control group. There were no significant variation in MN frequency and LOO between the exposed group residing within 61–80 m away from mobile stations and the control group. GSH, CAT and SOD were significantly lower in the exposed group residing within a distance range of 1–20 m ($p < 0.01$ for GSH; $p < 0.001$ for CAT; $p < 0.001$ for SOD), 21–40 m ($p < 0.05$ for GSH; $p < 0.001$ for CAT; $p < 0.001$ for SOD), 41–60 m ($p < 0.001$ for CAT; $p < 0.01$ for SOD) and 61–80 m ($p < 0.01$ for CAT; $p < 0.05$ for SOD) than individuals residing at least 300 m away from the base stations. However, GSH contents did not differ between the exposed group residing between 41 and 80 m from the base stations and controls (Table 4). The individuals exposed to a power density of ≤4 mW/m^2 and >4 mW/m^2 showed a higher MN frequency ($p < 0.05$ for ≤4 mW/m^2; $p < 0.001$ for >4 mW/m^2) and LOO ($p < 0.01$ for ≤4 mW/m^2; $p < 0.001$ for >4 mW/m^2) and lower GSH ($p < 0.05$ for ≤4 mW/m^2; $p < 0.01$ for >4 mW/m^2), CAT ($p < 0.01$ for ≤4mW/m^2; $p < 0.001$ for >4 mW/m^2) and SOD ($p < 0.05$ for ≤4 mW/m^2; $p < 0.001$ for >4 mW/m^2) (Table 4).

Multiple linear regression analyses revealed a significant association with low GSH concentration and age ($p < 0.05$), smoking habit ($p < 0.001$), daily mobile phone use ($p < 0.05$) and increasing power density ($p < 0.05$). A similar association has been reported with reduced CAT activity with increasing power density ($p < 0.001$) and alleviated SOD activity with smoking habit ($p < 0.05$) and increasing power density ($p < 0.001$) (Table 5). The analyses also showed a significant relationship between higher MN frequency with smoking habit ($p < 0.001$) and increasing power density ($p < 0.001$) and higher LOO with smoking habit ($p < 0.001$), alcohol consumption ($p < 0.05$) and increasing power density ($p < 0.001$) (Table 5). The parameter of mobile phone usage was not included in the multiple linear regression analysis due to multicollinearity with the duration of mobile phone use and average daily mobile phone use. Similarly, distance from the base stations showed multicollinearity with power density in the preliminary analysis; therefore, the former is also excluded in the multiple linear regression analysis.

Discussion

Mobile phone base stations have become an integral part of telecommunication, which use RFR to transmit the signals. These electromagnetic waves are generated by

Table 5. Multiple linear regression in the exposed and control groups.

	Characteristics	Durbin–Watson	Model-*F*	*B*-value	*t*-value	*p*-value
GSH	Age	2.22	6.62***	−0.24	−2.10	0.043
	Gender			0.11	1.09	0.283
	Dietary pattern			−0.10	−0.99	0.328
	Smoking habit			0.44	−3.86	0.001
	Alcohol consumption			−0.06	−0.47	0.640
	Duration of mobile phone use			−0.09	−0.69	0.492
	Daily mobile phone use			0.22	2.06	0.039
	Power density			−0.18	−1.97	0.041
CAT	Age	2.10	11.19***	−0.09	−0.94	0.352
	Gender			0.03	0.29	0.774
	Dietary pattern			0.01	0.12	0.907
	Smoking habit			−0.01	−0.07	0.950
	Alcohol consumption			0.03	0.29	0.771
	Duration of mobile phone use			0.01	0.08	0.944
	Daily mobile phone use			−0.07	−0.77	0.447
	Power density			−0.72	−8.93	0.001
SOD	Age	2.23	4.94***	0.01	0.11	0.911
	Gender			0.00	0.01	0.993
	Dietary pattern			−0.12	−1.22	0.237
	Smoking habit			−0.32	−2.70	0.012
	Alcohol consumption			0.01	0.10	0.923
	Duration of mobile phone use			0.11	0.81	0.426
	Daily mobile phone use			−0.07	−0.61	0.551
	Power density			−0.46	−4.74	0.001
LOO	Age	1.82	6.53***	0.22	1.96	0.052
	Gender			−0.13	−1.30	0.208
	Dietary pattern			0.11	1.13	0.262
	Smoking habit			0.47	4.12	0.001
	Alcohol consumption			−0.15	−1.25	0.210
	Duration of mobile phone use			−0.01	−0.05	0.965
	Daily mobile phone use			0.02	0.15	0.886
	Power density			0.37	3.99	0.001
MN	Age	2.17	11.10***	0.09	0.87	0.390
	Gender			−0.05	−0.58	0.572
	Dietary pattern			0.03	0.38	0.718
	Smoking habit			0.44	4.41	0.001
	Alcohol consumption			0.28	2.62	0.013
	Duration of mobile phone use			−0.04	−0.34	0.733
	Daily mobile phone use			0.06	0.58	0.562
	Power density			0.36	4.45	0.001

Values in bold are significant ($p < 0.05$).

electric charges that are rapidly accelerated to and fro in the transmitting antenna. Although RFR are nonionizing electromagnetic radiations, yet there has been a great concern about their deleterious effects on the human body as it is assumed that RFR could produce some of the biological effects akin to those produced by ionizing radiations such as X or γ-rays. Because of its adverse health effects reported worldwide, the presence of mobile base stations in the residential areas could be an electromagnetic threat, which is silently creeping in the lives of residents staying near the mobile base stations. We have therefore attempted to obtain an insight into the adverse effects of RFR in the inhabitants residing in the vicinity (within 80 m) of mobile base stations emitting RFR for mobile connectivity.

The frequency of nonspecific health symptoms such as nausea, loss of appetite, visual disturbance, irritability and depression were found to be significantly higher in the population living close (within 100 m) to mobile phone base stations as compared to those living away from these stations (Santini et al., 2002, 2003). Besides the nonspecific health symptoms of fatigue, headache, dizziness and muscle pain self-reported by the volunteers in the earlier study (Pachuau et al., 2015), the present study showed a significant increase in MN frequency and decreased antioxidants among inhabitants residing close to the base station/s when compared to controls. A number of studies have reported an increase in the DNA damage/micronuclei in different study systems. The human PBLs exposed to RFR have shown an increased frequency of micronuclei earlier (d'Ambrosio et al., 2002; Garaj-Vrhovac et al., 1992; El-Abd and Eltoweissy, 2012; Tice et al., 2002; Zotti-Martelli et al., 2000). Various studies conducted in other systems have also revealed an increased micronuclei frequency after exposure to RFR (Balode, 1996; Busljeta et al., 2004; Gandhi and Singh, 2005; Trosic et al., 2002, 2004). Our results are in agreement with a recent study where buccal mucosa cells showed increased micronuclei in mobile phone users (Banerjee et al., 2016). However, some of the studies did not find any increase in the MN frequency after RFR exposure both *in vitro* and *in vivo* (Bisht et al., 2002; Scarfi et al., 2006; Vijayalaxmi et al., 1997, 1999, 2001; Zeni et al., 2003, 2008), and such reports emphasized on the lack of thermal effects from RFR

(Vijaylaxmi and Obe, 2004), whereas the observed effect in the present study may be due to the interaction of RFR with various cellular macromolecules by producing ROS. This contention is supported by the fact that RFR-exposed individuals showed increased LOO and alleviated GSH contents, CAT and SOD activities in the present study. A similar effect has been observed earlier in the CAT activity in the rats exposed to low level of RFR (Achudume et al., 2010). Also, RFR emitted from cell phones led to oxidative stress in human semen (Agarwal et al., 2009). RFR (2.45 GHz) has been reported to cause a significant increase in the LOO of exposed Wistar rats (Aweda et al., 2003). The present study also revealed the induction of LOO by RF radiation, which could possibly react with DNA and produce lesions in it. The increased LOO has been reported in the plasma of rats with a decline in GSH and other antioxidants earlier (Aydin and Akar, 2011).

The highest measured power density was 7.52 mW/m^2. Most of the measured values close to base stations (Table 1) are higher than that of the safe limits recommended by Bioinitive Report 2012 (0.5 mW/m^2), Salzburg resolution 2000 (1 mW/m^2) and EU (STOA) 2001 (0.1 mW/m^2). However, all the recorded values were well below the current ICNIRP safe level (4700 mW/m^2) and the current Indian Standard (450 mW/m^2). Although cigarette smoking increased the MN frequency and decreased the antioxidants, the statistical analysis also revealed a close correlation between the power density and MN frequency and antioxidant status. Thus, the effects of RF radiation cannot be ignored as unrepaired DNA damage and oxidative stress are associated with several diseases such as cancer and several age-related diseases (Bernstein et al., 2013; Dart et al., 2013). The persistence of low level of DNA damage could have negative effect on human health.

The exact mechanism of action of RFR in micronuclei induction and reduced antioxidant status is not apparent. The possible putative mechanism of generation of DNA damage may be the production of endogenous free radicals due to continuous exposure. RFR has been reported to produce different free radicals earlier (Avci et al., 2009; Burlaka et al., 2013; Barcal et al., 2014; Kazemi et al., 2015). Cells possess a number of compensatory mechanisms to deal with ROS and its effects. Among these are the induction of antioxidant proteins such as GSH, SOD and CAT. Enzymatic antioxidant systems function by direct or sequential removal of ROS, thereby terminating their activities. An imbalance between the oxidative forces and antioxidant defense systems causes oxidative injury, which has been implicated in various diseases, such as cancer, neurological disorders, atherosclerosis, diabetes, liver cirrhosis, asthma, hypertension and ischemia (Andreadis et al., 2003; Comhair et al., 2005; Dhalla et al., 2000; Finkel and Holbrook, 2000; Kasparova et al., 2005; Sayre et al., 2001; Sohal et al., 2002). Because of the significant decrease in endogenous antioxidants and increased LOO among the exposed group, the extra burden of free radicals is unlikely to get neutralized, and these surplus ROS may react with important cellular macromolecules including DNA forming either DNA adducts or stand breaks, which may be later expressed as micronuclei once the cell decides to divide. The decline in the antioxidant status may be also due to the suppressed activity of Nrf2 transcription factor which is involved in maintaining the antioxidant status in the cells.

The present study has reported that RFR increased the frequency of MN and LOO and reduced GSH contents, CAT and SOD activities in the plasma of the exposed individuals. The induction of MN may be due to the increase in free-radical production. The present study demonstrated that staying near the mobile base stations and continuous use of mobile phones damage the DNA, and it may have an adverse effect in the long run. The persistence of DNA unrepaired damage leads to genomic instability which may lead to several health disorders including the induction of cancer.

Acknowledgements

The authors would like to acknowledge the cooperation extended by the participants without which the study would have not been completed. The authors are grateful to Prof. N. Senthilkumar for allowing us to use the instrument facility in the Department of Biotechnology, Mizoram University, State Biotech Hub Programme, Government of India, New Delhi. The authors wish to thank Dr. Lalrinthara Pachuau for his valuable assistance in power density measurements. We are grateful to Dr. C. Lalfamkima Varte for his assistance in statistical analyses.

Declaration of interest

The authors report no declarations of interest.

Funding

This work was supported by University Grants Commission, Govt. of India, New Delhi, vide grant number F.4-10/2010 (BSR).

References

Abdel-Rassoul, G., El-Fateh, O. A., Salem, M. A., et al. (2007). Neurobehavioral effects among inhabitants around mobile phone base stations. *Neurotoxicology*. 28:434–440.

Achudume, A., Onibere, B., Aina, F., et al. (2010). Induction of oxidative stress in male rats subchronically exposed to electromagnetic fields at non-thermal intensities. *JEMAA*. 2:482–487.

Aebi, H. (1984). Catalase in vitro. *Methods. Enzymol.* 105:121–126.

Agarwal, A., Desai, N. R., Makker, K., et al. (2009). Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: an in vitro pilot study. *Fertil. Steril.* 92:1318–1325.

Andreadis, A. A., Hazen, S. L., Comhair, S. A., et al. (2003). Oxidative and nitrosative events in asthma. *Free. Radic. Biol. Med.* 35:213–225.

Atasoy, H. I., Gunal, M. Y., Atasoy, P., et al. (2013). Immunohistopathologic demonstration of deleterious effects on growing rat testes of radiofrequency waves emitted from conventional Wi-Fi devices. *J. Pediatr. Urol.* 9:223–229.

Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Fact Sheet 3. (2011). Available from: www.arpansa.gov.au (accessed 23 December 2016).

Avci, B., Akar, A., Bilgici, B., et al. (2009). Oxidative stress induced by 1.8 GHz radio frequency electromagnetic radiation and effects of garlic extract in rats. *Int. J. Radiat. Biol.* 88:799–805.

Avendaño, C., Mata, A., Sanchez Sarmiento, C. A., et al. (2012). Use of laptop computers connected to internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation. *Fertil. Steril.* 97:39–45.

Aweda, M. A., Gbenebitse, S., Meidinyo, R. O. (2003). Effects of 2.45 GHz microwave exposures on the peroxidation status in Wistar rats. *Niger. Postgrad. Med. J.* 10:243–246.

Aydin, B., Akar, A. (2011). Effects of a 900-MHz electromagnetic field on oxidative stress parameters in rat lymphoid organs, polymorphonuclear leukocytes and plasma. *Arch Med Res.* 42(4):261–267.

Balode, Z. (1996). Assessment of radio-frequency electromagnetic radiation by the micronucleus test in bovine peripheral erythrocytes. *Sci. Total. Environ.* 180:81–85.

Banerjee, S., Singh, N. N., Sreedhar, G., et al. (2016). Analysis of the genotoxic effects of mobile phone radiation using buccal micronucleus assay: A comparative evaluation. *J. Clin. Diagn. Res.* 10:82–85.

Barcal, J., Stopka, P., Křížová, J., et al. (2014). High-frequency electromagnetic radiation and the production of free radicals in four mouse organs. *Act. Nerv. Super. Rediviva.* 56(1–2):9–14.

Bernstein, C., Nfonsam, V., Prasad, A. R., et al. (2013). Epigenetic field defects in progression to cancer. World. *J. Gastrointest. Oncol.* 5:43–49.

Beuege, J. A., Aust, S. D. (1978). Microsomal lipid peroxidation. *Method. Enzymol.* 30:302–310.

Bisht, K. S., Moros, E. G., Straube, W. L., et al. (2002). The effect of 835.62 MHz FDMA or 847.74 MHz CDMA modulated radiofrequency radiation on the induction of micronuclei in C3H 10T½ Cells. *Radiat. Res.* 157:506–515.

Bortkiewicz, A., Zmys'lony, M., Szyjkowska, A., et al. (2004). Subjective symptoms reported by people living in the vicinity of cellular phone base stations: Review. *Med. Pr.* 55:345–351.

Burlaka, A., Tsybulin, O., Sidorik, E., et al. (2013). Overproduction of free radical species in embryonal cells exposed to low intensity radiofrequency radiation. *Exp. Oncol.* 35(3):219–225.

Busljeta, I., Trosic, I., Milkovic-Kraus, S. (2004). Erythropoietic changes in rats after 2.45 GHz nonthermal irradiation. *Int. J. Hyg. Environ. Health.* 207:549–554.

Cherry, N. (2000). A new paradigm, the physical, biological and health effects of radio-frequency/microwave radiation. Available from: http://hdl.handle.net/10182/3973.

Comhair, S. A., Ricci, K. S., Arroliga, M., et al. (2005). Correlation of systemic superoxide dismutase deficiency to airflow obstruction in asthma. *Am. J. Respir. Crit. Care. Med.* 172:306–313.

d'Ambrosio, G., Massa, R., Scarfi, M. R., et al. (2002). Cytogenetic damage in human lymphocytes following GMSK phase modulated microwave exposure. *Bioelectromagnetics.* 23:7–13.

Dart, P., Cordes, K., Elliott, A., et al. (2013). Biological and health effects of microwave radiofrequency transmission. A review of the research literature. A report to the staff and directors of the Eugene water and electric board. Available from: www.national-toxic-encephalopathy-foundation.org/

Department of Telecommunications (DoT). (2012). Government of India Ministry of Communications & Information Technology Report of the Departmental Committee on BTS Towers. pp. 1–35. Available from: www.dot.gov.in/sites/default/files/Committee Report on BTS towers.

Dhalla, N. S., Temsah, R. M., Netticadan, T. (2000). Role of oxidative stress in cardiovascular diseases. *J. Hypertens.* 18:655–673.

Diem, E., Schwarz, C., Adlkofer, F., et al. (2005). Non-thermal DNA breakage by mobile-phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro. *Mutat. Res.* 583:178–183.

Eger, H., Hagen, K. U., Lucas, B., et al. (2004). The influence of being physically near to a cell phone transmission mast on the incidence of cancer. *Umwelt. Medizin. Gesellschaft.* 17:1–7.

El-Abd, S. F., Eltoweissy, M. Y. (2012). Cytogenetic alterations in human lymphocyte culture following exposure to radiofrequency field of mobile phone. *J. App. Pharm. Sci.* 2:16–20.

Fenech, M., Morley, A. A. (1985). Measurement of micronuclei in lymphocytes. *Mutat. Res.* 147:29–36.

Fenech, M., Chang, W. P., Kirsch-Volders, M., et al. (2003). HUMN project: detailed description of the scoring criteria for the cytokinesis-block micronucleus assay using isolated human lymphocyte cultures. *Mutat. Res.* 534:65–75.

Finkel, T., Holbrook, N. J. (2000). Oxidants, oxidative stress and the biology of aging. *Nature.* 408:239–247.

Fried, R. (1975). Enzymatic and non-enzymatic assay of superoxide dismutase. *Biochimie.* 57:657–660.

Gandhi, G., Anita. (2005). Genetic damage in mobile phone users: Some preliminary findings. *Indian J. Hum. Genet.* 11:99–104.

Gandhi, G., Kaur, G., Nisar, U. (2014). A cross-sectional case control study on genetic damage in individuals residing in the vicinity of a mobile phone base station. *Electromagn. Biol. Med.* 4:344–354.

Gandhi, G., Singh, P. (2005). Cytogenetic damage in mobile phone users: preliminary data. *Int. J. Hum. Genet.* 5:259–265.

Garaj-Vrhovac, V., Fucic, A., Horvat, D. (1992). The correlation between the frequency of micronuclei and specific chromosome aberrations in human lymphocytes exposed to microwave radiation in vitro. *Mutat. Res.* 281:181–186.

Gutteridge, J. M. C. (1995). Lipid peroxidation and antioxidant as biomarkers of tissue damage. *Clin. Chem.* 41:1819–1828.

Hardell, L., Nasman, A., Pahlson, A., et al. (1999). Use of cellular telephones and the risk for brain tumours: a case-control study. *Int. J. Oncol.* 15:113–116.

Hardell, L., Carlberg, M., Mild, K. H. (2013). Use of mobile phones and cordless phones is associated with increased risk for glioma and acoustic neuroma. *Pathophysiology.* 20:85–110.

Havas, M. (2013). Radiation from wireless technology affects the blood, the heart, and the autonomic nervous system. *Rev. Environ. Health.* 28:75–84.

Hutter, H. P., Moshammer, H., Wallner, P., et al. (2006). Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations. *Occup. Environ. Med.* 63:307–313.

International Agency for Research on Cancer (IARC). (2011). World Health Organization. Available from: www.iarc.fr (accessed 23 March 2017).

Jagetia, G. C., Jayakrishnan, A., Fernandes, D., et al. (2001). Evaluation of micronuclei frequency in the cultured peripheral blood lymphocytes of cancer patients before and after radiation treatment. *Mutat. Res.* 491:9–16.

Jagetia, G. C., Venkatesha, V. A. (2005). Effect of mangiferin on radiation-induced micronucleus formation in cultured human peripheral blood lymphocytes. *Environ. Mol. Mutagen.* 46:12–21.

Kasparova, S., Brezova, V., Valko, M., et al. (2005). Study of the oxidative stress in a rat of chronic brain hypoperfusion. *Neurochem. Int.* 46:601–661.

Kazemi E., Mortazavi, S.M.J., Ali-Ghanbari A., et al. (2015). Effect of 900 MHz electromagnetic radiation on the induction of ROS in human peripheral blood mononuclear cells. *J. Biomed. Phys. Eng.* 5(3):105–114.

Kerman, M., Senol, N. (2012). Oxidative stress in hippocampus induced by 900 MHz electromagnetic field emitting mobile phone: Protection by melatonin. *Biomed. Res.* 23:147–151.

Kunwar, A., Priyadarsini, K. (2011). Free radicals, oxidative stress and importance of antioxidants in human health. *J. Med. Allied. Sci.* 1:53–60.

Kwan-Hoong, N. (2005). Radiation, mobile phones, base stations and your health. Malaysia: Malaysian Communications and Multimedia Commission. (accessed 15 July 2016).

Lerchl, A., Klose, M., Grote, K., et al. (2015).Tumor promotion by exposure to radiofrequency electromagnetic fields below exposure limits for humans. *Biochem. Biophys. Res. Commun.* 459:585–590.

Levitt, B. B., Lai, H. (2010). Biological effects from exposure to electromagnetic radiation emitted by cell tower base stations and other antenna arrays. *Environ. Rev.* 18:369–395.

Li, L., Bisht, K. S., LaGroye, I., et al. (2001). Measurement of DNA damage in mammalian cells exposed in vitro to radiofrequency fields at sars of 3–5 w/kg. *Radiat. Res.* 156:328–332.

Lowry, O. H., Rosebrough, N. J., Randall, R. J. (1951). Protein measurement with the folin phenol reagent. *J. Biochem.* 193:265–275.

Maes, A., Van Gorp, U., Verschaeve, L. (2006). Cytogenetic investigation of subjects professionally exposed to radiofrequency radiation. *Mutagenesis.* 21:139–142.

McNamee, J. P., Bellier, P. V., Gajda, G. B., et al. (2003). No evidence for genotoxic effects from 24 h exposure of human leukocytes to 1.9 GHz radiofrequency fields. *Radiat. Res.* 159(5):693–697.

Moron, M. S., Depierre, J. W., Mannervik, B. (1979). Levels of glutathione, glutathione reductase and glutathione-*s*-transferase activities in rat lung and liver. *Biochim. Biophys. Acta.* 582:67–78.

Pachuau, L., Pachuau, Z., Zothansiama. (2015). Comparisons of non specific health symptoms faced by inhabitants exposed to high and low power density from mobile phone tower radiation. *Int. J. Recent. Innov. Trends. Comp. Commun.* 3:94–98.

Prosser, J. S., Moquet, J. E., Lloyd, D. C., et al. (1988). Radiation induction of micronuclei in human lymphocytes. *Mutat. Res.* 199:37–45.

Santini, R., Santini, P., Danze, J. M., et al. (2002). Study of the health of people living in the vicinity of mobile phone base stations I: Influences of distance and sex. *Pathol. Biol.* 50:369–373.

Santini, R., Santini, P., Danze, J. M., et al. (2003). Symptoms experienced by people in vicinity of base stations: II. Incidences of age, duration of exposure, location of subjects in relation to the antennas and other electromagnetic factors. *Pathol. Biol.* 51:412–415.

Sayre, L. M., Smith, M. A., Perry, G. (2001). Chemistry and biochemistry of oxidative stress in neurodegenerative disease. *Curr. Med. Che.* 8:721–738.

Scarfi, M. R., Fresegna, A. M., Villani, P., et al. (2006). Exposure to radiofrequency radiation (900 MHz, GSM signal) does not affect micronucleus frequency and cell proliferation in human peripheral blood lymphocytes: an interlaboratory study. *Radiat. Res.* 165:655–663.

Sohal, R. S., Mockett, R. J., Orr, W. C. (2002). Mechanisms of aging: An appraisal of the oxidative stress hypothesis. *Free. Radic. Biol. Med.* 33:575–586.

Sun, L. X., Yao, K., He, J. L., et al. (2006). DNA damage and repair induced by acute exposure of microwave from mobile phone on cultured human lens epithelial cells. *Zhonghua. Yan. Ke. Za. Zhi.* 42:1084–1088.

Tice, R. R., Hook, G. G., Donner, M., et al. (2002). Genotoxicity of radiofrequency signals. I. Investigation of DNA damage and micronuclei induction in cultured human blood cells. *Bioelectromagnetics.* 23:113–126.

Trosic, I., Busljeta, I., Kasuba, V., et al. (2002). Micronucleus induction after whole-body microwave irradiation of rats. *Mutat. Res.* 521:73–79.

Trosic, I., Busljeta, I., Modlic, B. (2004). Investigation of the genotoxic effect of microwave irradiation in rat bone marrow cells: in vivo exposure. *Mutagenesis.* 19:361–364.

Vijayalaxmi Mohan, N., Meltz, M. L., et al. (1997). Proliferation and cytogenetic studies in human blood lymphocytes exposed in vitro to 2450 MHz radiofrequency radiation. *Int. J. Radiat. Biol.* 72:751–757.

Vijayalaxmi Seaman, R. L., Belt, M. L., et al. (1999). Frequency of micronuclei in the blood and bone marrow cells of mice exposed to ultra-wideband electromagnetic radiation. *Int. J. Radiat. Biol.* 75(1):115–120.

Vijayalaxmi, Pickard, W. F., Bisht, K. S., et al. (2001). Cytogenetic studies in human blood lymphocyte exposed in vitro to radiofrequency radiation at a cellular telephone frequency (835.62 MHz, FDMA). *Radat. Res.* 155:113–121.

Vijayalaxmi, Obe, G. (2004). Controversial cytogenetic observations in mammalian somatic cells exposed to radiofrequency radiation. *Radiat. Res.* 162:481–496.

Wolf, R., Wolf, D. (2004). Increased incidence of cancer near a cellphone transmitter station. *Int. J. Cancer. Prev.* 1:1–19.

Yakymenko, I., Tsybulin, O., Sidorik, E., et al. (2015). Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation. *Electromagn. Biol. Med.* 19:1–16.

Yildirim, M. S., Yildirim, A., Zamani, A. G., et al. (2010). Effect of mobile phone station on micronucleus frequency and chromosomal aberrations in human blood cells. *Gen. Couns.* 21:243–251.

Zeni, O., Schiavoni, A., Sannino, A., et al. (2003). Lack of genotoxic effects (micronucleus induction) in human lymphocytes exposed in vitro to 900 MHz electromagnetic fields. *Radiat. Res.* 160:152–158.

Zeni, O., Schiavoni, A., Perrottam, A., et al. (2008). Evaluation of genotoxic effects in human leukocytes after in vitro exposure to 1950 MHz UMTS radiofrequency field. *Bioelectromagnetics*. 29:177–184.

Zotti-Martelli, L., Peccatori, M., Scarpato, R., et al. (2000). Induction of micronuclei in human lymphocytes exposed in vitro to microwave radiation. *Mutat. Res.* 472:51–58.

Cell Towers - Cancer; Environmental radiofrequency radiation at the Järntorget Square in Stockholm Old Town, Sweden in May, 2018 compared with results on brain and heart tumour risks in rats exposed to 1.8 GHz base station environmental emissions, World Academy of Sciences Journal. (Hardell et al); 2018

Environmental radiofrequency radiation at the Järntorget Square in Stockholm Old Town, Sweden in May, 2018 compared with results on brain and heart tumour risks in rats exposed to 1.8 GHz base station environmental emissions

LENNART HARDELL[1,2], MICHAEL CARLBERG[1,2], LENA K. HEDENDAHL[2], TARMO KOPPEL[3] and MIKKO AHONEN[4]

[1]Department of Oncology, Faculty of Medicine and Health, Örebro University, SE-701 82 Örebro;
[2]The Environment and Cancer Research Foundation, SE-702 17, Örebro, Sweden;
[3]Department of Labour Environment and Safety, Tallinn University of Technology, 19086 Tallinn;
[4]Institute of Environmental Health and Safety, 11615 Tallinn, Estonia

Received October 30, 2018; Accepted November 29, 2018

DOI: 10.3892/wasj.2018.5

Abstract. Radiofrequency (RF) radiation in the frequency range 30 kHz to 300 GHz was evaluated in 2011 by the International Agency for Research on Cancer (IARC) at WHO to be a 'possible human carcinogen' Group 2B. The conclusion was based on human epidemiological studies on an increased risk of glioma and acoustic neuroma. In previous measurement studies, we found high environmental RF radiation levels at certain public places and also in an apartment in Stockholm, Sweden. One such place was the Järntorget square in the Stockholm Old Town. The EME Spy exposimeter was used for these studies. We have now conducted a field spatial distribution measurement with a radiofrequency broadband analyser. The maximum E-field topped at 11.6 V/m at the centre of the square, where the antenna was focused. Järntorget's mean value was 5.2 V/m, median 5.0 V/m, range 1.2-11.6 V/m. Of interest is that this level can be compared to a lifespan carcinogenicity study on rats exposed to 1.8 GHz GSM environmental radiation performed at the Ramazzini Institute (RI) in Italy. A statistically significant increase in the incidence of malignant schwannoma in the heart was found in male rats at the highest dose, 50 V/m. In treated female rats at the highest dose, the incidence of malignant glial tumours was increased, although this was not statistically significant. On the whole, the findings of this study showed that RF radiation levels at one square, Järntorget, in Sweden, were only one order of magnitude lower than those showing an increased incidence of tumours in the RI animal study. An increased cancer risk cannot be excluded for those working in the proximity of Järntorget for longer time periods.

Correspondence to: Professor Lennart Hardell, *Present address*: The Environment and Cancer Research Foundation, Studievägen 35, SE 702 17 Örebro, Sweden
E-mail: lennart.hardell@environmentandcancer.com

Key words: radiofrequency radiation, microwaves, measurement, base stations, exposure, health, cancer

Introduction

Radiofrequency (RF) radiation from wireless devices, such as mobile and cordless phones, base stations, and so on in the frequency range 30 kHz to 300 GHz was classified in 2011, as a ‘possible human carcinogen’ Group 2B by the International Agency for Research on Cancer (IARC), a part of WHO (1,2). In spite of that evaluation, little or mostly nothing has been done to inform and protect the population from RF radiation (3,4). On the contrary, human exposure has increased rapidly in recent years and will increase substantially with the introduction of the fifth generation (5G) for wireless communication (5-7).

Of special concern is the involuntary environmental exposure to RF radiation. This is the situation in most places with few or no possibilities to avoid exposure. Thus, RF radiation should by now be regarded as environmental pollution that is hard to detect using our senses.

Previously, we reported RF radiation levels in different places in Stockholm in Sweden, such as at the Central Railway station (8), the Old Town (9), in an apartment close to base stations (10) and in the City (11).

High ambient exposure was found at several places, and particularly at the Järntorget square in the Old Town, that was measured in April, 2016 [mean, 24,277.1 μW/m^2 (3.03 V/m); median, 19,990.0 μW/m^2 (2.75 V/m); ranging from 257.0 μW/m^2 (0.31 V/m) to 173,301.8 μW/m^2 (8.08 V/m)] (9).

Recently, the US National Toxicology Program (NTP) released results from their large animal two-year study on cell phone RF radiation exposure (12,13) that we have discussed in further detail elsewhere (14). A statistically significant

increased risk was found for brain glioma and malignant schwannoma in heart nerves, but also in other organs. There was some evidence of an increased risk of thyroid cancer, and clear evidence that RF radiation is a multi-site carcinogen (14). These results are similar to those found in human epidemiological studies, as reviewed elsewhere (7,15,16).

In the study by the Ramazzini Institute (RI) in Italy, rats were exposed from prenatal life until natural death to a 1.8 GHz GSM far field of 0, 5, 25, 50 V/m with a whole-body exposure for 19 h/day similar to that from base stations. Increased incidence of similar tumour types that have been associated in individuals using wireless phones were found (17). Thus, a statistically significant increase in the incidence of malignant schwannoma in the heart was found in male rats at the highest dose, 50 V/m. An increased incidence of heart Schwann cell hyperplasia was observed in the treated male and female rats at the highest dose (50 V/m), but was not statistically significant. In treated female rats at the highest dose (50 V/m), the incidence of malignant glial tumours was increased, although this was not statistically significant.

The aim of this study was to make additional measurements at Järntorget in Stockholm Old city (Fig. 1) and to compare the levels with the results from the RI study (17). This was a measurement study with no involvement of test persons. Thus, no ethical permission was required.

Materials and methods

Study design. Field spatial distribution measurements were conducted with a radiofrequency broadband analyser. The square was covered with spot measurements, whereas in each spot the field was measured with slow circular movements to cover a 1 sqm area at heights of 0.7-2 m. In order to minimize field perturbation by the measurer, the meter was held at arm's lengths from the investigator, with the outward extending probe. The measurements were conducted in about 0.8-0.9 m from the investigator. On the whole, 51 spots were measured in the square and the street area connected to the square.

The radiofrequency broadband analyser make and model was Wandell & Goltermann EMR300, E-field probe 2244/90. The characteristics include: A resolution of 0.01 V/m; settling time typically 1 sec; displaying instantaneous measured value, maximum value and average value.

The E-field probe used had the following characteristics: A frequency range 100 kHz to 3 GHz, measurement range 0.6 to 800 V/m, linearity 0.7 to 3 dB depending on the amplitude, frequency response ±2.4 dB and isotropy deviation ±1.0 dB. At each spot, the average electric field in Volts per meter (V/m) was recorded.

An EME Spy 200 exposimeter was also used in this study. The exposimeter measures 20 predefined frequency bands, as presented in Table I. They cover the frequencies of most public RF radiation emitting devices currently used in Sweden. The exposimeter covers frequencies from 88 to 5,850 MHz. For FM, TV3, TETRA, TV4&5, Wi-Fi 2G and Wi-Fi 5G the lower detection limit is 0.01 V/m (0.27 μW/m^2); for all other bands the lower detection limit is 0.005 V/m (0.066 μW/m^2). For all bands the upper detection limit is 6 V/m (95,544 μW/m^2; 9.5544 μW/cm^2). The sampling time used in this study was 4 sec which is the fastest for the given exposimeter.

Table I. Predefined measurement frequency bands of EME Spy 200 Exposimeter Frequency ranges.

Frequency band	Frequency MIN (MHz)	Frequency MAX (MHz)
FM	88	107
TV3	174	223
TETRA I	380	400
TETRA II	410	430
TETRA III	450	470
TV4&5	470	770
LTE 800, 4G (DL[a])	791	821
LTE 800, 4G (UL[b])	832	862
GSM 900 + UMTS 900, 3G (UL)	880	915
GSM 900 + UMTS 900, 3G (DL)	925	960
GSM 1800 (UL)	1,710	1,785
GSM 1800 (DL)	1,805	1,880
DECT	1,880	1,900
UMTS 2100, 3G (UL)	1,920	1,980
UMTS 2100, 3G (DL)	2,110	2,170
Wi-Fi, 2 GHz	2,400	2,483.5
LTE 2600, 4G (UL)	2,500	2,570
LTE 2600, 4G (DL)	2,620	2,690
WiMax	3,300	3,900
Wi-Fi 5 GHz	5,150	5,850

[a]DL, down link; transmission from base station to mobile phone; [b]UL, up link, transmission from mobile phone to base station.

The exposimeter measures different telecommunications protocols: Frequency modulation (FM) radio broadcasting; television (TV) broadcasting; TETRA emergency services (police, rescue, etc.); global system for mobile communications (GSM) second generation mobile communications; universal mobile telecommunications systems (UMTS) third generation mobile communications, 3G; long-term evolution (LTE) fourth generation mobile communications standard, 4G; digital European cordless telecommunications (DECT) cordless telephone systems standard; Wi-Fi wireless local area network protocol; worldwide interoperability for microwave access (WIMAX) wireless communication standard for high speed voice, data and internet. The location of the mobile phone base station antenna at the square is presented in Fig. 2.

Results

Järntorget, Stockholm Old Town. The field spatial distribution measurement conducted at Järntorget square (Fig. 3) illustrates the propagation of the microwaves from the mobile phone base station's several antennas. Based on the radiofrequency broadband analyser spot measurements, the maximum E-field topped at 11.6 V/m at the centre of the square, where the antenna is focused. The Järntorget's mean value was 5.2 V/m; median, 5.0 V/m; range, 1.2-11.6 V/m; whereas in the whole square the field level was nowhere below 2 V/m. When distancing from

Figure 1. The map shows the location of Järntorget square in The Old Town at Stockholm city. Map from Lantmäteriet, Sweden.

Figure 2. Järntorget square in Stockholm; the red circle indicates a mobile phone base station antenna.

the square, into the narrow streets, the field level gradually dropped; note top in figure scale 11.43 V/m.

Fig. 4 depicts different radiofrequency components at Järntorget across different communication bands. The main contributors to the radiofrequency exposure, time averaged over half an hour period, were all mobile telephony bands: LTE 2600 DL 1.7 V/m, GSM+UMTS 900 DL 1.6 V/m, LTE 800 DL 1.2 V/m, UMTS 2100 DL 0.9 V/m.

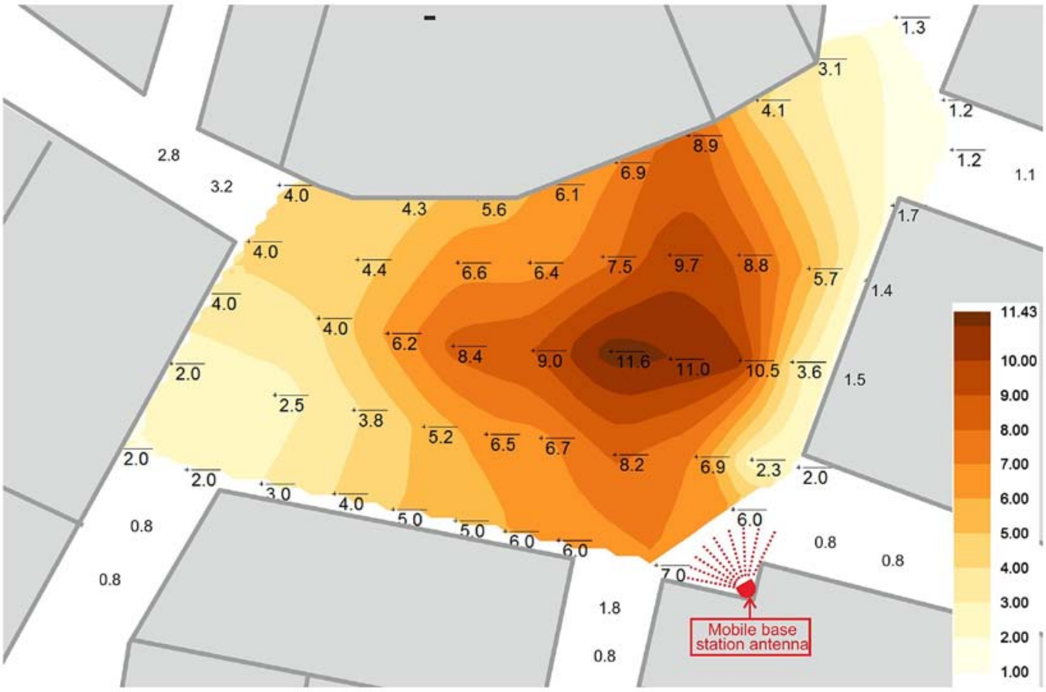


Figure 3. Järntorget square radiofrequency E-field distribution, units in Volts per meter (V/m), 5.05.2018 12:00, measured by a broadband meter (Wandell & Goltermann EMR-300) covering 100 kHz to 3 GHz.

Discussion

Ramazzini Institute rat study. In this lifespan carcinogenicity study, Sprague-Dawley rats were exposed to 1.8 GHz GSM environmental radiation (17). A statistically significant increase in the incidence of malignant schwannoma in the heart was found in male rats at the highest dose, 50 V/m, corresponding to 0.66 mW/cm^2 (6,63 W/m^2) and whole-body SAR of 0.1 W/Kg (Fig. 5.)

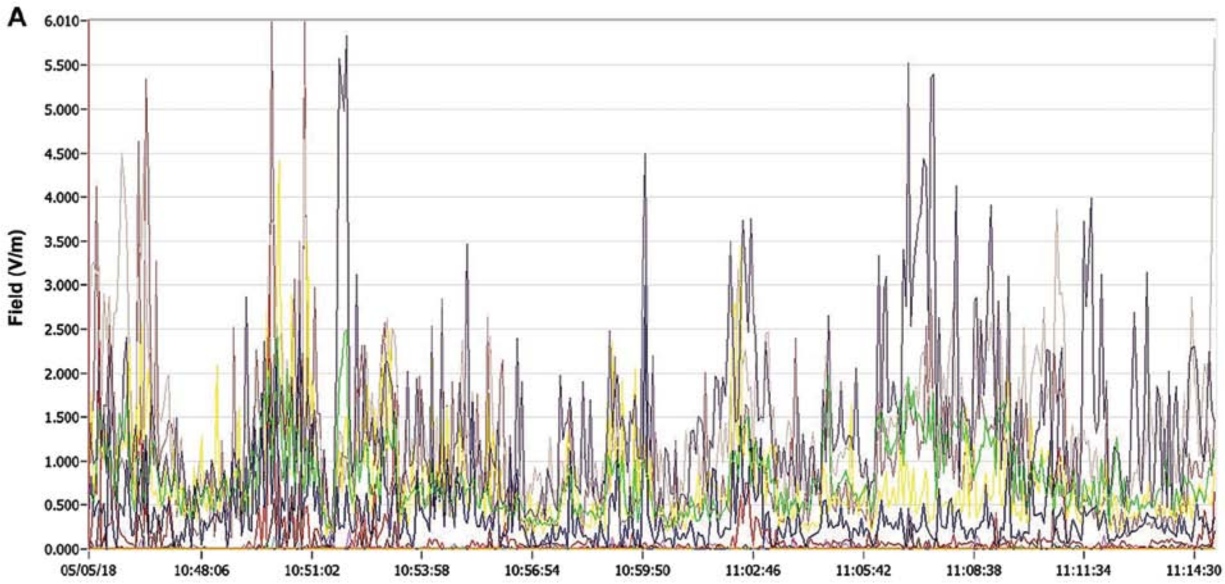
An increased incidence of heart Schwann cell hyperplasia was observed in the treated male and female rats at the highest dose (50 V/m), although this was not statistically significant (Fig. 6). In the treated female rats at the highest dose (50 V/m) the incidence of malignant glial tumours was increased, although this was not statistically significant (Fig. 7). No conclusive evidence on glia cell hyperplasia was found (Fig. 8).

More prominent effects on health due to lower compared to higher RF radiation exposure have been observed in studies, which could indicate a frequency and power-window based response. This has been shown in studies with RF-radiation exposure down to peak power output of 1 mW from a GSM mobile phone, where the blood brain barrier opened and led to leakage into the brain tissues of large molecules, e.g., albumin and big molecules that can be toxic to brain tissue (18,19). In the Ramazzini Institute study, it was shown in Figs. 7 and 8, that 25 V/m yielded a higher incidence of glial cell hyperplasia and glia cell malignant tumours in male rats, than exposure to 50 V/m.

In this study we used a broadband meter, Wandell & Goltermann EMR-300, covering 100 kHz to 3 GHz for measuring radiofrequency E-field distribution, units in Volts per meter. The measurement was done at midday on May 5, 2018 and encompassed the Järntorget square in the Stockholm Old Town. That place was selected since in our previous study with measurements from 2016, the Järntorget square had the highest RF radiation levels in the Old Town (see Table VI and Fig. 11 in that publication) (9).

The new spot measurements carried out in Järntorget square illustrate very high exposure levels at a popular tourist destination. The square was crowded with tourists and the local population either walking or sitting in the open-air cafés. The exposure levels in the entire square were needlessly high, as mobile communications services could be provided to subscribers in the square at orders of magnitude less power as presently used. This investigation revealed that mobile telephony service providers create unnecessary high exposure at public places, by using relatively high output power in base station antennas positioned close to people. Sufficient service coverage could be provided with much less radiation levels and carefully selected positions for base station antennas.

We measured the RF radiation at Järntorget with a mean of 5.2 V/m, a median of 5.0 V/m and a range of 1.2-11.6 V/m. Interestingly, the mean and median levels were only one order of magnitude lower than the radiation in the RI study, 50 V/m, with a statistically significant increase in the incidence of malignant schwannoma in the heart in male rats. In the same exposure group, an increased incidence of glia cell tumours in the brain was found in female rats. Based on thermal effects, a safety factor of 10 has been used for workers and additionally one fifth of that level for individuals with increased vulnerability, such as children, those with illness and otherwise sensitive individuals yielding a specific absorption rate (SAR) of 2 W/kg for mobile phones. This safety factor is based on acute thermal effects on the ape's eye with 100 W/kg yielding lens clouding [see the study by Lin (20)]: 'Clearly, the motivation was to limit temperature rises inside the eye to prevent formation of lens



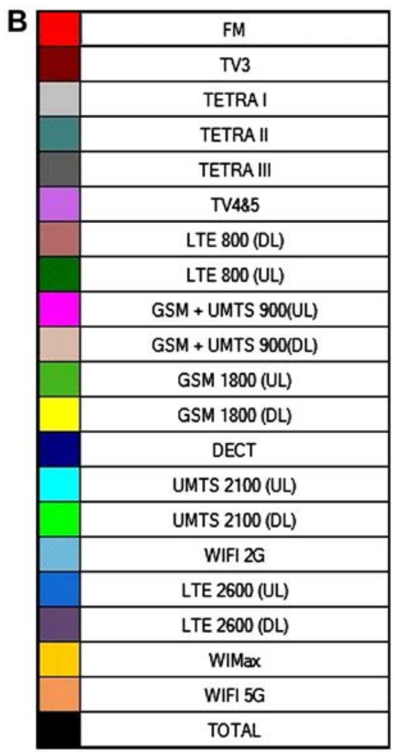


Figure 4. Radiofrequency components in Järntorget square across different communication bands (A and B); the horizontal axis of time represents walking around the square. Same colours for the different bands are used in (A and B).

opacity-cataracts. Specifically, a safety factor of ten was applied to reduce the SAR threshold of 100 to 10 W/kg. To provide for an additional margin of safety for the general public, an extra factor of five was introduced to arrive at 2 W/kg over 10 g of contiguous tissue, including the eye'. Using the same logic in safety factors as for SAR regarding the RI results would yield 2.5 V/m as a safety level. Thus, our results at Järntorget exceed that RF radiation magnitude.

The literature on cancer risks relating to RF radiation from base stations is limited. A review on 10 studies up to 2009 revealed that eight of these studies showed either neurobehavioral effects or cancer in populations living <500 m from a base station (21).

A review by Levitt and Lai (22) listed 56 studies. Exposure from base stations and other antenna arrays revealed changes in animals, humans and biological material in immunological and reproductive systems, as well as DNA double-strand breaks, influence on calcium movement in the heart and increased proliferation rates in human astrocytoma cancer cells.

The mean distance to base station for registered address at birth among 1,397 cancer cases aged 0-4 years during 1999-2001 and 5,588 birth controls was similar among the cases and controls (23). The total calculated power output within 700 m of the addresses yielded a statistically significant difference. The study had limited power to detect an increased cancer risk, since it was performed during a time period before the massive increase in ambient RF radiation from base stations, a relatively long distance to the base station and a short follow-up time.

A study from Brazil included 7,191 cancer deaths during 1996 to 2006, most of these, 93.5%, within an area of 500 m from the base stations (24). The mortality rate decreased outside that area. The largest accumulated electric field measured was 12.4 V/m and the lowest 0.4 V/m. The density power varied between 400 $\mu W/m^2$ to 407,800 $\mu W/m^2$. Our measured RF radiation levels at Järntorget were within that range.

Cancer incidence and mortality data were investigated after an alleged cancer cluster in West Midlands, UK following the installation of a mobile phone base station (25). A total of 19 persons had developed cancer, but did not fulfil criteria for cancer cluster, standardized mortality rates (SMR) for all cancer excluding non-melanoma skin cancers was for all persons 1.27, and 95% confidence interval (CI) =1.06-1.51 during 2001-2003.

Environmental exposure to RF radiation and the risk of malignant lymphoma was investigated in a case-control study in Sardinia, Italy (26). Self-reported distance of the three longest held residential addresses for 322 cases and

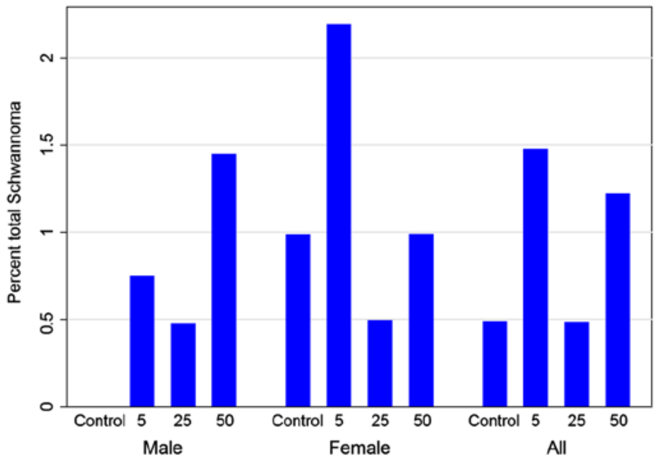


Figure 5. Total schwannoma incidence according to Table 2 in the study by Falcioni *et al* (17).

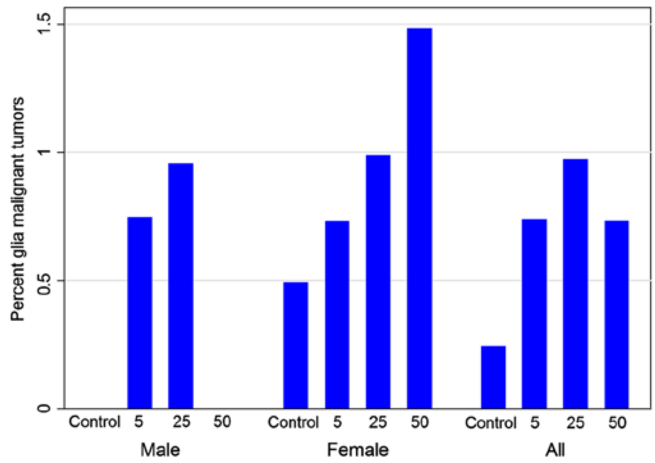


Figure 7. Glia cell malignant tumours according to Table 3 in the study by Falcioni *et al* (17).

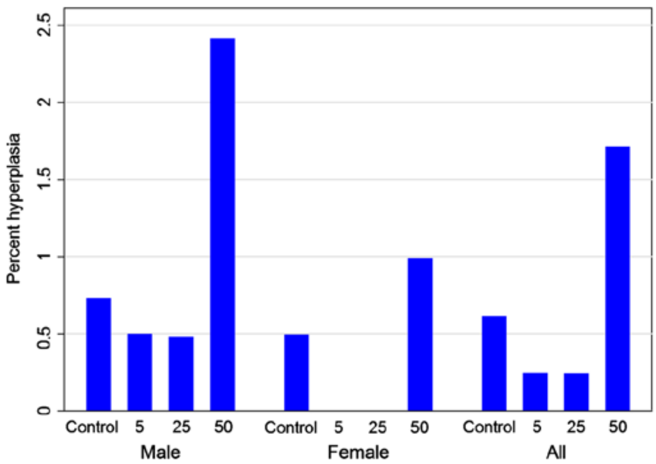


Figure 6. Schwann cell hyperplasia according to Table 2 in the study by Falcioni *et al* (17).

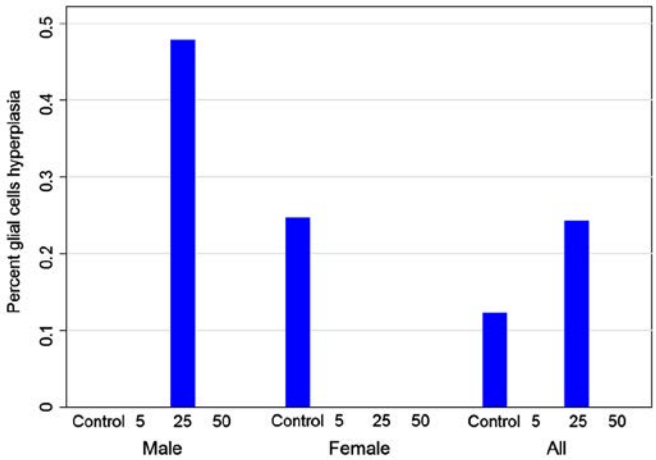


Figure 8. Glia cell hyperplasia according to Table 3 in the study by Falcioni*et al* (17).

444 controls were analysed for radio-TV transmitters and base stations. In addition, some measurements of exposure were done. Residence within 50 meters to a fixed radio-TV transmitter yielded overall for lymphoma odds ratio (OR) =2.7, and 95% CI =1.5-4.6. For mobile base stations no association was found.

Long term studies on low exposure to RF radiation on humans have shown influence on the neurotransmitters adrenaline, noradrenaline, dopamine and phenylethylamine when a GSM 900 MHz base station was installed in the village of Rimbach in Germany (27) and cortisol and thyroid hormones in people living near base stations (28,29). The chronic dysregulation of psychobiological stress markers may contribute to health problems and chronic illnesses.

Genetic damage using comet assay in blood leucocytes was used in 63 persons residing within 300 m from a base station and 28 healthy controls (30). DNA migration length, genetic damage frequency and damage index were statistically significantly elevated in the sample group compared to the controls. The power density was statistically significantly higher for the cases than for the controls. The linear regression analysis revealed daily mobile phone use, location of residence and power density as statistically significant predictors of genetic damage.

DNA damage was also analysed in a study group of 40 persons residing within 80 m of mobile phone base stations compared with a control group living 300 m or more from base stations (31). Multiple linear regression analyses revealed in the exposed group statistically significantly elevated micronucleus activity and lipid peroxidation and reduced concentrations of some analysed antioxidants (glutathione, catalase and superoxide dismutase).

In conclusion, this study demonstrated RF radiation levels at one square, Järntorget, in Stockholm, Sweden one order of magnitude lower than those showing an increased incidence of tumours (schwannoma and glioma) in the RI animal study with life-long exposure to 1.8 GHz base station environmental radiation. These results indicate that an increased cancer risk may be the situation for individuals staying at the square, primarily for those working in shops and cafés around the square. We have not measured RF radiation emissions in apartments around the square. It cannot be excluded that at certain places, the radiation may even be higher than those now measured, c.f. Hardell *et al* (10).

Acknowledgements

Not applicable.

Funding

The study was supported by grants from Mr. Brian Stein, Cancerhjälpen (Stockholm, Sweden) and the Pandora-Foundation for Independent Research, Berlin, Germany.

Availability of data and materials

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

All authors participated in the conception, design and writing of the manuscript and have read and approved the final version. MC constructed all Figures based on the study by Falcioni *et al* (17). TK made measurements of radiofrequency radiation levels.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

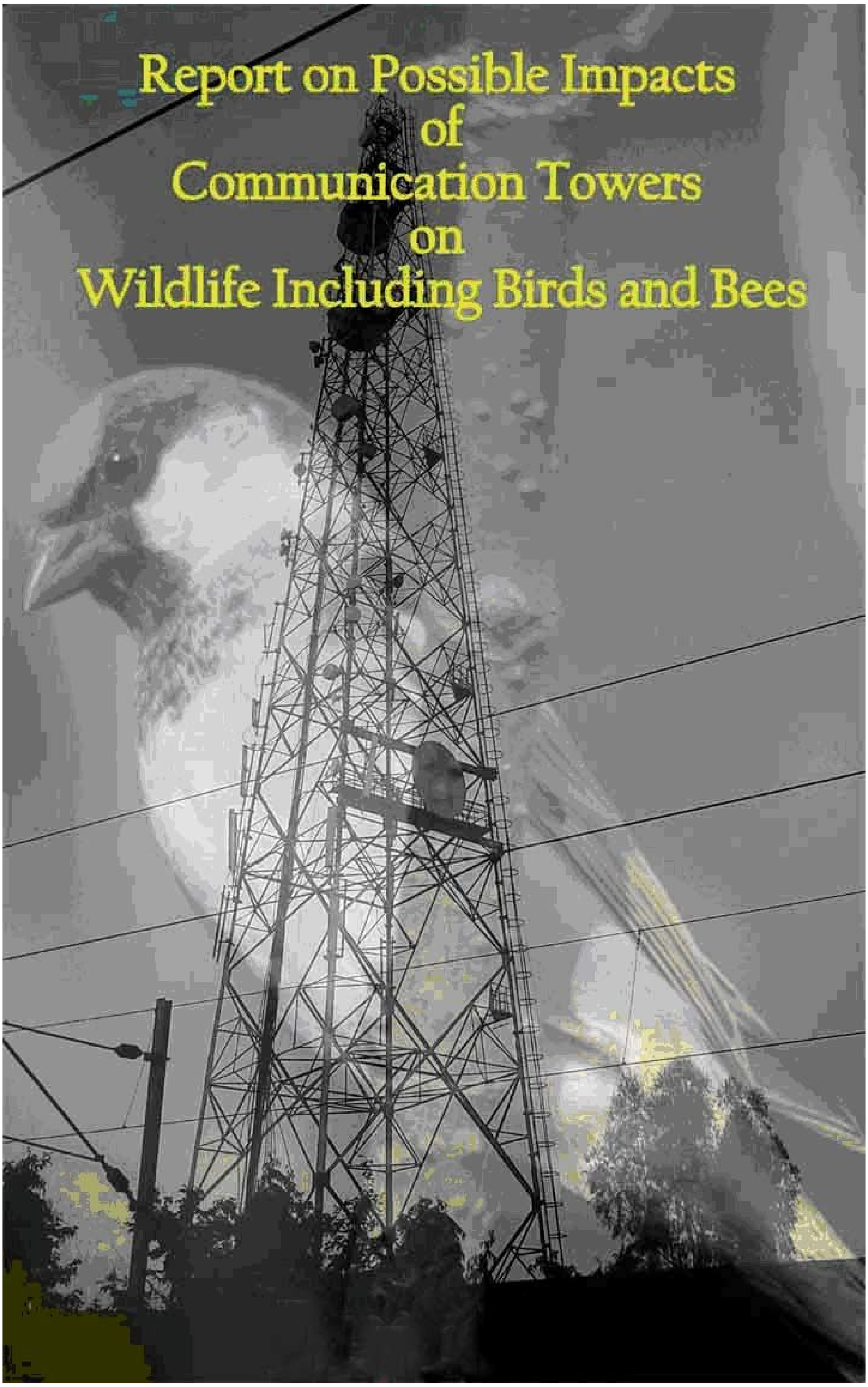
The authors declare that they have no competing interests.

References

1. Baan R, Grosse Y, Lauby-Secretan B, El Ghissassi F, Bouvard V, Benbrahim-Tallaa L, Guha N, Islami F, Galichet L and Straif K; WHO International Agency for Research on Cancer Monograph Working Group: Carcinogenicity of radiofrequency electromagnetic fields. Lancet Oncol 12: 624-626, 2011.
2. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. In: Non-Ionizing Radiation, Part 2: Radiofrequency Electromagnetic Fields. Vol 102. Lyon, France: International Agency for Research on Cancer; 2013. http://monographs.iarc.fr/ENG/Monographs/vol102/mono102.pdf. Accessed October 30, 2018.
3. Starkey SJ: Inaccurate official assessment of radiofrequency safety by the Advisory Group on Non-ionising Radiation. Rev Environ Health 31: 493-503, 2016.
4. Hardell L: World Health Organization, radiofrequency radiation and health - a hard nut to crack (Review). Int J Oncol 51: 405-413, 2017.
5. The 5G appeal: Scientists and doctors warn of potential serious health effects of 5G. http://www.5gappeal.eu/scientists-and-doctors-warn-of-potential-serious-health-effects-of-5g/. Accessed October 30, 2018.
6. Törnevik C: Impact of EMF limits on 5G networkr oll-out. ITU Workshop on 5G, EMF & Health, Warsaw, December 5th 2017. https://www.itu.int/en/ITU-T/Workshops-and-Seminars/20171205/Documents/S3_Christer_Tornevik.pdf. Accessed October 30, 2018.
7. Belpomme D, Hardell L, Belyaev I, Burgio E and Carpenter DO: Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective. Environ Pollut 242: 643-658, 2018.
8. Hardell L, Koppel T, Carlberg M, Ahonen M and Hedendahl L: Radiofrequency radiation at Stockholm Central Railway Station in Sweden and some medical aspects on public exposure to RF fields. Int J Oncol 49: 1315-1324, 2016.
9. Hardell L, Carlberg M, Koppel T and Hedendahl L: High radiofrequency radiation at Stockholm Old Town: An exposimeter study including the Royal Castle, Supreme Court, three major squares and the Swedish Parliament. Mol Clin Oncol 6: 462-476, 2017.
10. Hardell L, Carlberg M and Hedendahl LK: Radiofrequency radiation from nearby base stations gives high levels in an apartment in Stockholm, Sweden: A case report. Oncol Lett 15: 7871-7883, 2018.
11. Carlberg M, Hedendahl LK, Koppel T and Hardell L: High ambient radiofrequency radiation in Stockholm city, Sweden. Oncol Lett (In press).
12. National Toxicology Program: NTP technical report on the toxicology and carcinogenesis studies in Hsd:Sprague Dawley sd rats exposed to whole-body radio frequency radiation at a frequency (900 MHz) and modulations (GSM and CDMA) used by cell phones. NTP TR 595, March 26-28, 2018. https://ntp.niehs.nih.gov/ntp/about_ntp/trpanel/2018/march/tr595peerdraft.pdf. Accessed October 30, 2018.
13. National Toxicology Program: NTP technical report on the toxicology and carcinogenesis studies in B6C3F1/N mice exposed to whole-body radio frequency radiation at a frequency (1,900 MHz) and modulations (GSM and CDMA) used by cell phones. NTP TR 596, March 26-28, 2018. Available from: https://ntp.niehs.nih.gov/ntp/about_ntp/trpanel/2018/march/tr596peerdraft.pdf. Accessed October 30, 2018.
14. Hardell L and Carlberg M: Comments on the US National Toxicology Program technical reports on toxicology and carcinogenesis study in rats exposed to whole-body radiofrequency radiation at 900 MHz and in mice exposed to whole-body radiofrequency radiation at 1,900 MHz. Int J Oncol: 54: 111-127, 2019.
15. Hardell L, Carlberg M, Söderqvist F and Mild KH: Pooled analysis of case-control studies on acoustic neuroma diagnosed 1997-2003 and 2007-2009 and use of mobile and cordless phones. Int J Oncol 43: 1036-1044, 2013.
16. Carlberg M and Hardell L: Evaluation of mobile phone and cordless phone use and glioma risk using the Bradford Hill viewpoints from 1965 on association or causation. BioMed Res Int 2017: 9218486, 2017.
17. Falcioni L, Bua L, Tibaldi E, Lauriola M, De Angelis L, Gnudi F, Mandrioli D, Manservigi M, Manservisi F, Manzoli I, *et al*: Report of final results regarding brain and heart tumors in Sprague-Dawley rats exposed from prenatal life until natural death to mobile phone radiofrequency field representative of a 1.8 GHz GSM base station environmental emission. Environ Res 165: 496-503, 2018.
18. Nittby H, Brun A, Eberhardt J, Malmgren L, Persson BR and Salford LG: Increased blood-brain barrier permeability in mammalian brain 7 days after exposure to the radiation from a GSM-900 mobile phone. Pathophysiology 16: 103-112, 2009.
19. Eberhardt JL, Persson BR, Brun AE, Salford LG and Malmgren LO: Blood-brain barrier permeability and nerve cell damage in rat brain 14 and 28 days after exposure to microwaves from GSM mobile phones. Electromagn Biol Med 27: 215-229, 2008.
20. Lin JC: Safety standards for human exposure to radio frequency radiation and their biological rationale. IEEE Microw Mag 4: 22-26, 2003.
21. Khurana VG, Hardell L, Everaert J, Bortkiewicz A, Carlberg M and Ahonen M: Epidemiological evidence for a health risk from mobile phone base stations. Int J Occup Environ Health 16: 263-267, 2010.
22. Levitt BB and Lai H: Biological effects from exposure to electromagnetic radiation emitted by cell tower base stations and other antenna arrays. Environ Rev 18: 369-395, 2010.
23. Elliott P, Toledano MB, Bennett J, Beale L, de Hoogh K, Best N and Briggs DJ: Mobile phone base stations and early childhood cancers: Case-control study. BMJ 340: c3077, 2010.
24. Dode AC, Leão MM, Tejo FA, Gomes AC, Dode DC, Dode MC, Moreira CW, Condessa VA, Albinatti C and Caiaffa WT: Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil. Sci Total Environ 409: 3649-3665, 2011.
25. Stewart A, Rao JN, Middleton JD, Pearmain P and Evans T: Mobile telecommunications and health: Report of an investigation into an alleged cancer cluster in Sandwell, West Midlands. Perspect Public Health 132: 299-304, 2012.

26. Satta G, Mascia N, Serra T, Salis A, Saba L, Sanna S, Zucca MG, Angelucci E, Gabbas A, Culurgioni F, *et al*: Estimates of Environmental Exposure to Radiofrequency Electromagnetic Fields and Risk of Lymphoma Subtypes. Radiat Res 189: 541-547, 2018.
27. Buchner K and Eger H: Changes of clinically important neurotransmitters under the influence of modulated RF fields-A long-term study under real-life conditions. Umwelt-Medizin-Gesellschaft 24: 44-57, 2011 (In German).
28. Augner C, Hacker GW, Oberfeld G, Florian M, Hitzl W, Hutter J and Pauser G: Effects of exposure to GSM mobile phone base station signals on salivary cortisol, alpha-amylase, and immunoglobulin A. Biomed Environ Sci 23: 199-207, 2010.
29. Eskander EF, Estefan SF and Abd-Rabou AA: How does long term exposure to base stations and mobile phones affect human hormone profiles? Clin Biochem 45: 157-161, 2012.
30. Gandhi G, Kaur G and Nisar U: A cross-sectional case control study on genetic damage in individuals residing in the vicinity of a mobile phone base station. Electromagn Biol Med 34: 344-354, 2015.
31. Zothansiama ZM, Zosangzuali M, Lalramdinpuii M and Jagetia GC: Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations. Electromagn Biol Med 36: 295-305, 2017.

Cell Towers; Indian Government, Ministry of Environment and Forest, Report on Possible Impacts of Communication Towers on Wildlife Including Birds and Bees. 919 studies reviewed; 2011


Report on Possible Impacts
of
Communication Towers
on
Wildlife Including Birds and Bees

Expert Group to study the possible impacts of communication towers on Wildlife including Birds and Bees

Executive summary

India is one of the fastest growing mobile telephony industries in the world. It is estimated that by 2013, 1 billion plus people will be having cell phone connection in India. To support this growth of cell phone subscriber in the country, there has also been a tremendous growth of infrastructure in the form of mobile phone towers. Today, in absence of any policy on infrastructure development and location of cell phone towers, large numbers of mobile phone towers are being installed in a haphazard manner across urban and rural areas including other sparsely populated areas in India.

The transmission towers are based on the electromagnetic waves, which over prolonged usage have adverse impacts on humans as well as on other fauna. The adverse effects of electromagnetic radiation from mobile phones and communication towers on health of human beings are well documented today. However, exact correlation between radiation of communication towers and wildlife, are not yet very well established.

The Ministry of Environment and Forests usually receives several questions regarding this issue. In view of one such Lok Sabha Starred question regarding 'Ill effects of Mobile Towers on Birds' received on 11th August, 2010, an 'Expert committee to Study the possible Impacts of Communication Towers on Wildlife including Birds and Bees' was constituted on 30th August, 2010 by Ministry of Environment and Forest, Government of India.

The Expert Committee had five important mandates which are as follows:

I. To review all the studies done so far in India and abroad on aspects of ill effects of mobile towers on animals, birds and insects.

II. To assess the likely impacts of the growth in the number of mobile towers in the country

III. To suggest possible mitigatory measures.

IV. To formulate guidelines for regulating the large-scale installation of mobile towers in the country

V. To identify the gap areas for conducting further detailed research.

The Committee studied all the peer reviewed articles/ journals published on the impact of radiations on wildlife throughout the world and compiled them. Subsequently, detailed analysis of the papers was done to find out the impacts of electronic magnetic fields (**EMF**) on wildlife

including birds and bees and the gap areas for conducting further detailed research were identified.

The review of existing literature shows that the Electro Magnetic Radiations (EMRs) are interfering with the biological systems in more ways than one. There had already been some warning bells sounded in the case of bees and birds, which probably heralds the seriousness of this issue and indicates the vulnerability of other species as well. The electromagnetic radiations are being associated with the observed decline in the population of sparrow in London and several other European cities (Balmori, 2002, Balmori, 2009, Balmori & Hallberg, 2007). In case of bees, many recent studies have linked the electromagnetic radiations with an unusual phenomenon known as 'Colony Collapse Disorder'. A vast majority of scientific literature published across the world indicate deleterious effects of EMFs in various other species too.

In spite of the recent studies indicating possible harmful impact of EMF on several species, there are no long-term data available on the environmental impacts of EMRs as of now. Studies on impact of cell phone towers and EMR on birds and other wildlife are almost non-existent in India. Moreover, pollution from EMRs being a relatively new environmental issue, there is a lack of established standard procedures and protocols to study and monitor the EMF impacts especially among wildlife, which often make the comparative evaluations between studies difficult. In addition to the gap areas in research, the necessary regulatory policies and their implementation mechanism also have not kept pace with the growth of mobile telephoning. Our guidelines on exposure limits to EMF need to be refined since the ICNIRP Standard currently followed in India is coined based on only thermal impact of Radio Frequency and are dismissive of current epidemiological evidence on impacts of non-thermal nature on chronic exposure from multiple towers. Meanwhile, the precautionary principle should prevail and we need to better our standards on EMF to match the best in the world.

Along with the growth of phone towers and subscribers, India is also witnessing a rapid population growth. To feed and support this rapidly growing population the agricultural security and the factors influencing them should be of concern. However, the population of many species such as honey bees, which is one of the most important pollinator and important factor for agricultural productivity, has seen a drastic population drop. Unfortunately we do not have much data about the effects of EMR available for most of our free-living floral and faunal species in India. Therefore, there is an urgent need to do further research in this area before it would be too late.

Introduction

During recent years, there has been an increase in the usage of telecommunication devices, which has become an easy means for communication. The use of mobiles have become more conspicuous, during the last decade and this has led to construction of transmission towers in large numbers, both in the urban, as well as in rural areas including other sparsely populated areas. Transmission towers are based on the electromagnetic waves, which over prolonged usage have adverse impacts on humans as well as on other fauna. The adverse effects of electromagnetic radiation from mobile phones and communication towers on health of human beings are well documented today. Recently the electromagnetic fields from mobile phones and other sources have been classified as "possibly carcinogenic to human" by the WHO's International Agency for Research on Cancer (IARC). However, exact correlation between radiation of communication towers and wildlife, are not yet very well established. Though, there have been growing concerns about the impacts of mobile towers on wildlife, and couple of studies conducted in India and worldwide indicates the possibility of negative effects of radiation.

The Ministry of Environment and Forests (MoEF) usually receives questions on such subject during the last couple of years. One such question, that the Ministry of Environment and Forests replied to on 11th August, 2010 was a Lok Sabha Starred question number 244 regarding 'Ill effects of Mobile Towers on Birds'. In the above mentioned question, Hon'ble Member of Parliament (Lok Sabha), wanted to know, whether any studies have been conducted on the ill effects of mobile towers on birds and bees and also whether the Government has set up any committee to look into the issue.

In view of this, an urgent need was felt to constitute an Expert Group to assess the level of possible impacts of growth of mobile towers in urban, sub-urban and even rural/forest areas on the wildlife including birds and bees and to suggest appropriate mitigative measures for the problem. Hence, the 'Expert committee to Study the possible impacts of communication towers on wildlife including Birds and Bees' was constituted on 30th August, 2011 by Ministry of Environment and Forest, Government of India. The constitution and the terms of references of the committee are at **Annexure I.**

The committee had the following important five mandates to be completed:

I. To review all the studies done so far in India and abroad on aspects of ill effects of mobile towers on animals, birds and insects.

II. To assess the likely impacts of the growth in the number of mobile towers in the country

III. To suggest possible mitigatory measures.

IV. To formulate guidelines for regulating the large-scale installation of mobile towers in the country

V. To identify the gap areas for conducting further detailed research.

In order to achieve its mandate, the committee had convened three meetings and discussed the issue thread bare. After the discussions, in third meeting, the committee had decided to finalise its report. Subsequently, hundreds of research papers were collated, analyzed and reviewed. Detailed descriptions were noted of important and relevant papers. Drafts were circulated within the Committee members for comments.

It should be noted that this is not a complete review of the impact of the electromagnetic radiation on all life forms as **the mandate of the Committee was limited to birds and bees.** However, for the context purpose the committee has referred to many papers concerning other taxa (See Literature Cited).

The findings of the committee based on the above mandates are provided in detail in the following paragraphs.

<u>Scientific background on the issue</u>

Rapid developments in various fields of science and technology in recent years have intensified the human interference into the natural environment and associated physical, biological and ecological systems resulting in various unintended and undesirable negative impacts on environment. With economic, social and scientific development, increasingly fresh avenues for environmental pollution are being thrown open in recent times. Pharmaceutical, genetic, nano-particulates and electro-magnetic pollutions are the prominent ones among them which were in the limelight in recent times for all the negative reasons.

The intensity of manmade electromagnetic radiation has become so ubiquitous and it is now increasingly being recognized as a form of unseen and insidious pollution that might perniciously be affecting life forms in multiple ways (Balmori 2006a; Balmori 2006b; Balmori 2009; Tanwar 2006). The **electro-magnetic fields** (**EMF**) as a pollution called 'electro-smog' is unique in many ways. Unlike most other known pollutants, the **electro-magnetic radiations** (**EMR**) are not readily perceivable to human sense organs and hence not easily detectable. However, their impacts are likely to be insidious and chronic in nature. However, it is possible that other living beings are likely to perceive these fields and get disturbed or sometimes fatally misguided. Because the EMR pollution being relatively recent in origin and lately being recognized as a pollutant coupled with its expected long-term impacts and lack of data on its effect on organisms, the real impacts of these pollutants are not yet fully documented in the scientific literature.

The electromagnetic radiations (EMR) are extensively used in modern communication and technology. Radio waves and microwaves are forms of electromagnetic energy that are collectively described by the term "**radiofrequency**" or "**RF**". RF emissions and associated phenomena can be discussed in terms of "energy", “power”, "radiation" or "field". Electromagnetic "radiation" can best be described as waves of electric and magnetic energy moving together (i.e., radiating) through space (Cleveland, Fields, and Ulcek 1999).

The first mobile telephone service started on the non-commercial basis on 15 August 1995 in Delhi. During the last 16 years, India has seen exponential growth of mobile telephoning. With this growth, a number of private and government players are coming in to this lucrative and growing sector. At present nearly 800 million Indians have mobile phones, making it the second largest mobile subscribers in the world after China. At present, there are nearly 15 companies providing mobile telephoning. However, necessary regulatory policies and their implementation mechanism have not kept pace with the growth of mobile telephoning. Moreover, there have been not enough scientific studies on the impact of mobile phone towers on human health or its environmental impacts.

Most of the short-term studies primarily looking into the thermal impacts of EMR exposure on biological systems have neither succeeded to detect any statistically significant changes in the biological processes nor could prove any acute change in health conditions at the present background levels of exposures (Brent 1999; Hanowski Niemi and Blake 1996; Hoskote, Kapdi and Joshi 2008; Lönn *et al.* 2005; Mixson *et al.* 2009; Zach and Mayoh 1984; Zach and Mayoh 1986). On the other hand, long-term studies have reported alarming observations, detecting negative consequences on immunity, health, reproductive success, behaviour, communication, co-ordination, and niche breadth of species and communities (Preece *et al.* 2007; Levitt and Lai 2010; Hardell *et al.* 2008; Hardell *et al.* 2007; Fernie and Bird 2001).

- **<u>Impact on birds and bees:</u>** Of the non-human species, impacts on birds and bees appear to be relatively more evident. Exposure to EMR field is shown to evoke diverse responses varying from aversive behavioural responses to developmental anomalies and mortality in many of the studied groups of animals such as bees, amphibians, mammals and birds (Zach and Mayoh 1982; Zach and Mayoh 1982; Batellier et al. 2008; Nicholls and Racey 2007; Bergeron 2008; Copplestone et al. 2005; Sahib 2011). Honey bees appear to be very sensitive to EMF (Ho 2007; Sharma and Kumar 2010; Ho 2007) and their behavioural responses, if scientifically documented, could be used as an indicator of EMF pollution.

- **<u>Impacts on other wildlife:</u>** Other wildlife such as amphibians and reptiles also appear to be at high risk with possible interference of EMF with metamorphosis and sex ratios where temperature dependent sex determination is operational. Several investigations into

environmental effects of EM fields are covered in some of the unpublished / grey literature and impact assessments submitted to various regulatory government agencies (Bergeron 2008a; Bergeron 2008b; Cleveland, Fields, and Ulcek 1999; Copplestone *et al.* 2005; G. Kumar 2010; Hutter *et al.* 2006). Such reports are either not in the public domain, or scattered and often difficult to access.

- **Impacts on Human**: Since its inception, there have been concerns about the ill-effect of the mobile towers and mobile phones. Despite being a relatively newly acknowledged form of pollution, EMRs and their negative impacts on biological systems and environment have already been reported by several studies. However most of the available scientific literature on the negative environmental effects of electromagnetic fields reports the results of experimental and epidemiological studies examining the impact on various aspects of human health (Tanwar 2006; Savitz 2003; Preece *et al.* 2007; Oberfeld *et al.* 2004; Navarro *et al.* 2003; Lönn *et al.* 2005; Kundi and Hutter 2009; Hardell *et al.* 2007; Kapdi, S. Hoskote and Joshi 2008; Hallberg and Johansson 2002).

Present scenario: At present, there could be more than 5 billion mobile phone subscribers globally (www.who.ilt/mediacentre/factsheets/fs193/en). Recently, in May 2011, the WHO's International Agency for Research on Cancer (IARC) has classified electromagnetic fields from mobile phones and other sources "possibly carcinogenic to human" and advised the public to adopt safety measures to reduce exposures, like use of hand-free devices or texting. For details please see Press Release No. 208, dated 31 May 2011 on IARC-WHO (http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf). Their findings were published in the July 2011 issue of the medical journal ***Lancet***. Later, WHO clarified that some of the findings published in ***Lancet*** were not reported properly in the media and the risk is not as great as made out in the media. Some of the cell phone manufactures have objected to these findings (For example see www.Physorg.com). Some earlier investigators also have contended that there is no measurable risk of reproductive failure and birth defects from EMF exposures in humans (Brent *et al.* 1993), while several others do not agree with that conclusion (Gandhi 2005; Kapdi, Hoskote and Joshi 2008; Pourlis 2009; G. Kumar 2010). Studies carried out on the RF levels in North India, particularly at the mobile tower sites at Delhi have shown that people in Indian cities are exposed to dangerously high levels of EMF pollution (Tanwar 2006).

Existing world-wide standard and permissible limits

Two major transmission protocols currently in use for mobile telephony are GSM (900 to 1800 MHz) and CDMA (824-844 MHz paired with 869-889 MHz). The Telecom Engineering Centre (TEC) of DoT had proposed display of Specific Absorption Rate (SAR) value in handsets. As indicated in the table below, current Indian standards on exposure are much higher than many other countries.

Power Density (W/m^2)	International Exposure limits adopted by various countries
10	FCC (USA) OET-65, Public Exposure Guidelines at 1800 MHz
9.2	**ICNIRP and EU recommandation 1998 – Adopted in India**
3	Canada (Safety Code 6, 1997)
2	Australia
1.2	Belgium (ex Wallonia)
0.5	New Zealand
0.24	Exposure limit in CSSR, Belgium, Luxembourg
0.1	Exposure limit in Poland, China, Italy , Paris
0.095	Exposure limit in Italy in areas with duration > 4hours
0.095	Exposure limit in Switzerland
0.09	ECOLOG 1998 (Germany) *Precaution recommendation only*
0.025	Exposure limit in Italy in sensitive areas
0.02	**Exposure limit in Russia (since 1970), Bulgaria, Hungary**
0.001	"Precautionary limit" in Austria, Salzburg City only
0.0009	*BUND 1997 (Germany) Precaution recommendation only*
0.00001	**New South Wales, Australia**

Table 1. Guidelines and Limits on Exposure Limits in Various Countries (Source: Girish Kumar 2010)

1. ICNIRP Guidelines (International Radiofrequency Guidelines):

In April 1998, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) published, guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields in the frequency range up to 300 GHz. These guidelines replaced previous advice issued in 1988 and 1990. The main objective of the ICNIRP Guidelines is to establish guidelines for limiting EMF exposure that will provide protection against known adverse health effects (ICNIRP, 1998). An adverse health effect is defined by ICNIRP as one which causes detectable impairment of the health of the exposed individual or of his or her offspring; a biological effect, on the other hand, may or may not result in an adverse health effect.

2. Guidelines and Limits followed by Other Countries:

Some countries have established new, low-intensity based exposure standards that respond to studies reporting effects that do not rely on heating. Consequently, new exposure guidelines are having hundreds or thousands times lower than those of Institution of Electronics and Electrical Engineers (IEEE) and ICNIRP. Table 2, shows some of the countries that have lowered their limits, for example, in the cell phone frequency range of 800 MHz to 900 MHz. The levels range from 10 microwatts per centimeter squared in Italy and Russia to 4.2 microwatts per centimeter squared in Switzerland. In comparison, the United States and Canada limit such exposures to only 580 microwatts per centimeter squared (at 870MHz) and then averaged over a time period (meaning that higher exposures are allowed for shorter times, but over a 30 minute period, the average must be 580 microwatts per centimeter squared or less at this frequency). The United Kingdom allows one hundred times of this level, or 580 x 100 microwatts per centimeter squared. Higher frequencies have higher safety limits, so that at 1000 MHz, for example, the limit is 1000 microwatts per centimeter squared (in the United States). The exposure standards for each individual frequency in the radiofrequency radiation range needs to be calculated. These are presented as reference points only. Emerging scientific evidence has encouraged some countries to respond by adopting planning targets, or interim action levels that are responsive to low-intensity or non-thermal radiofrequency radiation bio effects and health impacts.

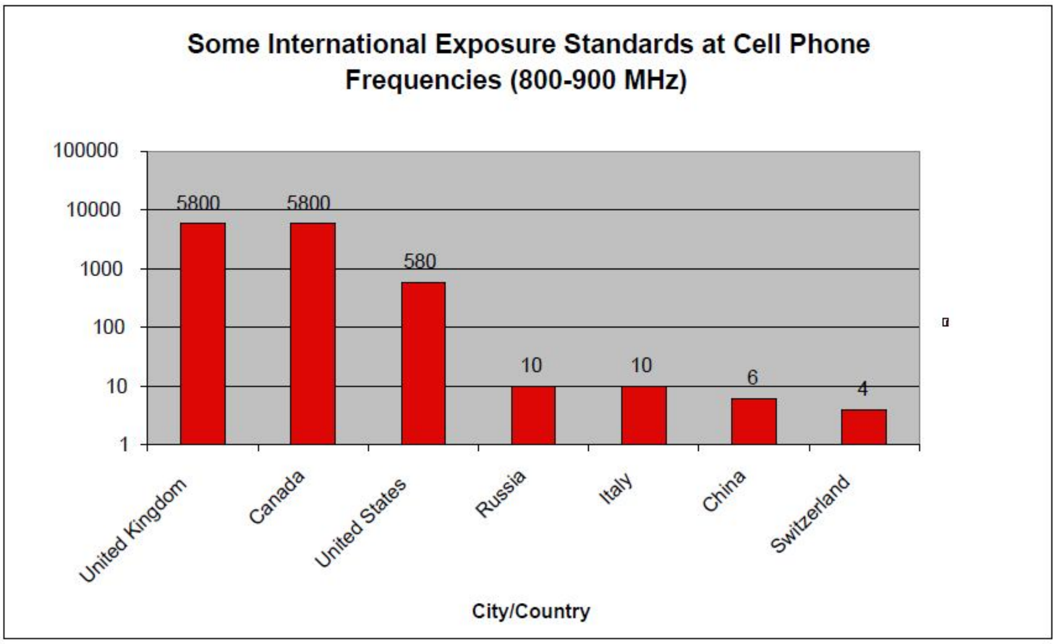


Table 2. Some International Exposure Standards at Cell Phone Frequencies (800-900 MHz) (Values of exposure in microwatts per centimeter squared)

Professional bodies such as IEEE and ICNIRP continue to support "thermal-only" guidelines:

a) by omitting or ignoring study results reporting bio-effects and adverse impacts to health and wellbeing from a very large body of peer-reviewed, published science because it is not yet "proved" according to their definitions;
b) by defining the proof of "adverse effects" at an impossibly high a bar (scientific proof or causal evidence) so as to freeze action;
c) by requiring a conclusive demonstration of both "adverse effect" and risk before admitting low-intensity effects should be taken into account;
d) by ignoring low-intensity studies that report bio-effects and health impacts due to modulation;
e) by conducting scientific reviews with panels heavily burdened with industry experts and under-represented by public health experts and independent scientists with relevant low-intensity research experience;
f) by limiting public participation in standard-setting deliberations; and other techniques that maintain the status quo.

(Source: "*Bio Initiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF)*" by 'Cindy Sage, and David Carpenter (2007)**)**

Detailed analysis of the Issue vis-à-vis the TORs

- **TOR I:** ***To review all the studies done so far in India and abroad on aspects of ill effects of mobile towers on animals, birds and insects.***

Though EMR is a relatively newly recognised pollutant, many recent studies have pointed to their harmful long-term impacts on health and environment. Hence the most important mandate of the committee was to study all the peer reviewed articles/ journals published on the impact of radiations on wildlife throughout the world and to compile them. Subsequently, detailed analysis of the papers was done to find out the impacts of electronic magnetic fields (**EMF**). The research papers were then listed in to three categories: showing impact on organisms, no impact and neutral or inconclusive evidence (See Table No. 3).

Literature review:

A review during the international seminar entitled "Effects of electromagnetic fields on the living environment" held in Ismaning, Germany in 1999, organized under WHO's International EMF Project, observed that the EMF impacts on environment are minimal and localized and has opined that the human EMF exposure limits recommended by the International Commission on Non-Ionizing Radiation (ICNIRP, 1998) would also be protective of the environment as well (Foster and Repacholi 1999). However, recent research reports are at odds with these propositions, including the latest report from WHO indicating a possible link with cell phone use and brain glioma (Baan *et al*, 2011).

Several species are known to have the capability to sense and respond to EM fields, especially the earth's magnetic field (Kirschvink 1982). However, little is known of the exact physiological mechanisms involved. Three major hypotheses of magnetic-field detection have been proposed (Lohmann and Johnsen 2000): a) *Electromagnetic induction* (as in Electro sensitive sharks and rays), b) *Biogenic magnetite* and c) *Chemical reactions modulated by magnetic fields*. Despite notable recent progress, primary magneto-receptors have not yet been identified unambiguously.

Most of the reported studies examined (n=919) deal with the EMF impacts on human subjects (81%), while only 3% of them reports impact on birds and just 2% on wildlife. The present report is based on relevant papers and documents obtained mainly from online archives of JSTOR (www.jstor.org) and Google scholar (http://scholar.google.co.in/). Salient features of the reported studies on the impact of EMF on different faunal groups are discussed below (can be included below).

An Analysis of Results of Literature Survey:

After careful screening that involved deletion of duplicate records and addition of new references, the 1080 references initially compiled for the analysis of literature (which formed the base for our overview) were reduced to 919 references. These final 919 study reports are used here for the present final analysis.

The studies were broadly classified based on the subject organisms into four categories- Birds, Bees, Other Animals (including wildlife) and humans. Based on the study's findings regarding the impact of EMFs on the subject, each category was further subdivided into three groups- Impact, No Impact or Neutral/ Inconclusive, as given in table 3 below. As noted below majority of the studies reported negative impacts by EMFs.

Table 3. Number of research studies (collected from Open access Bibliographic databases) collected and collated based on the study subjects and results

	Impact	**No Impact**	**Neutral/ inconclusive**	**Total (n)**
Birds	23	3	4	30
Bees	6	1	0	7
Human	459	109	174	742
Other Animals (+Wildlife)	85(+13)	16(+1)	10(+7)	111(+21)
Plants	7	0	1	8
Total	593	130	196	**919**

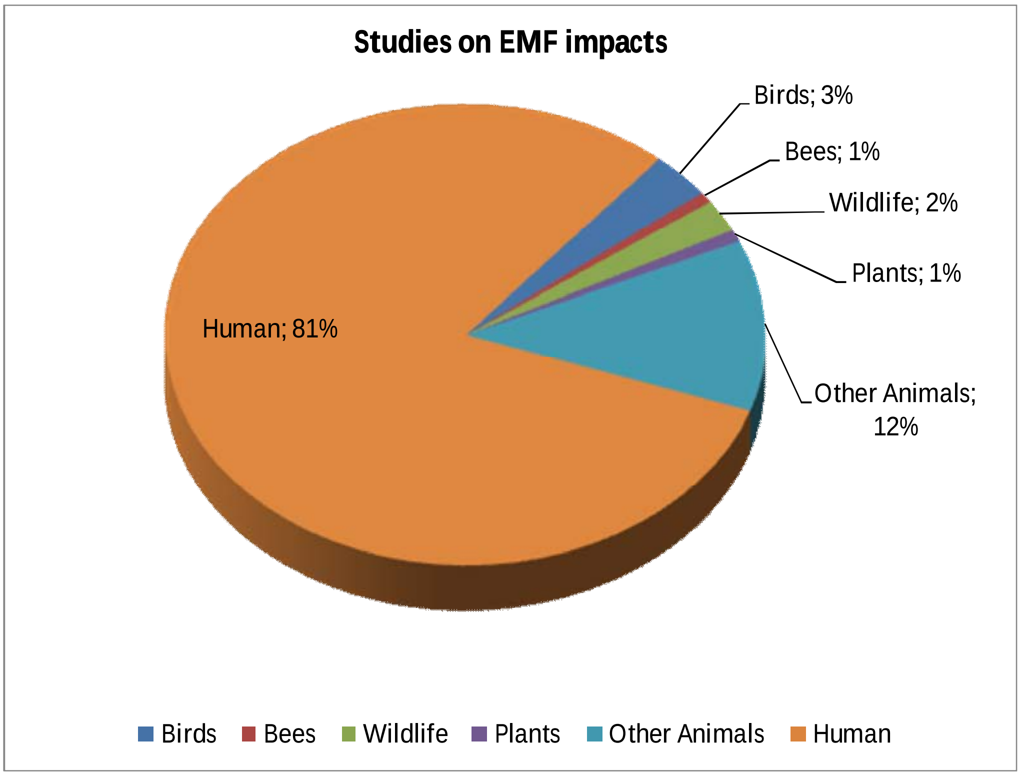


Fig 1. Proportion of studies on different groups of organisms

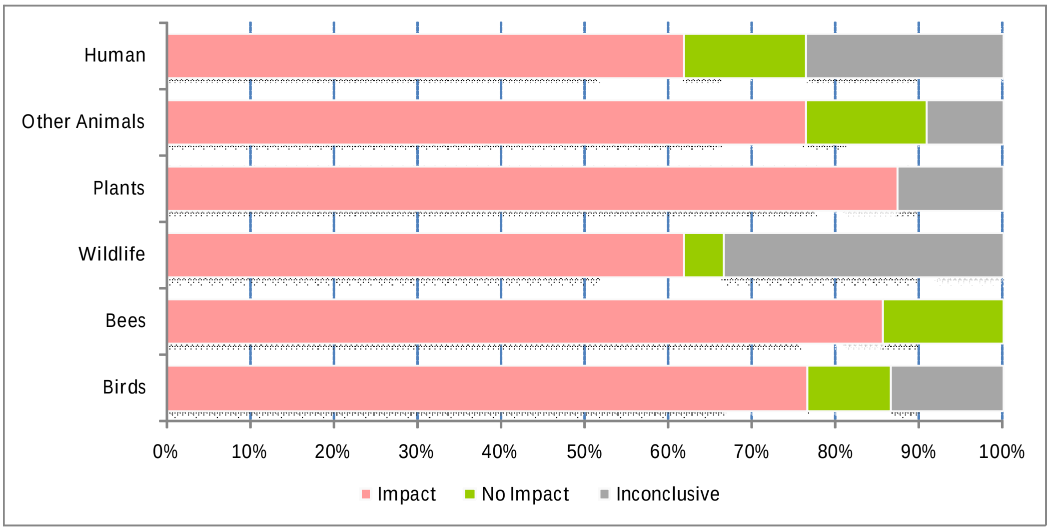


Fig 2. Proportion of study results in various groups of organisms (n=919). The 'Impact' (in red) indicates percentage of studies that reported harmful effect of EMR

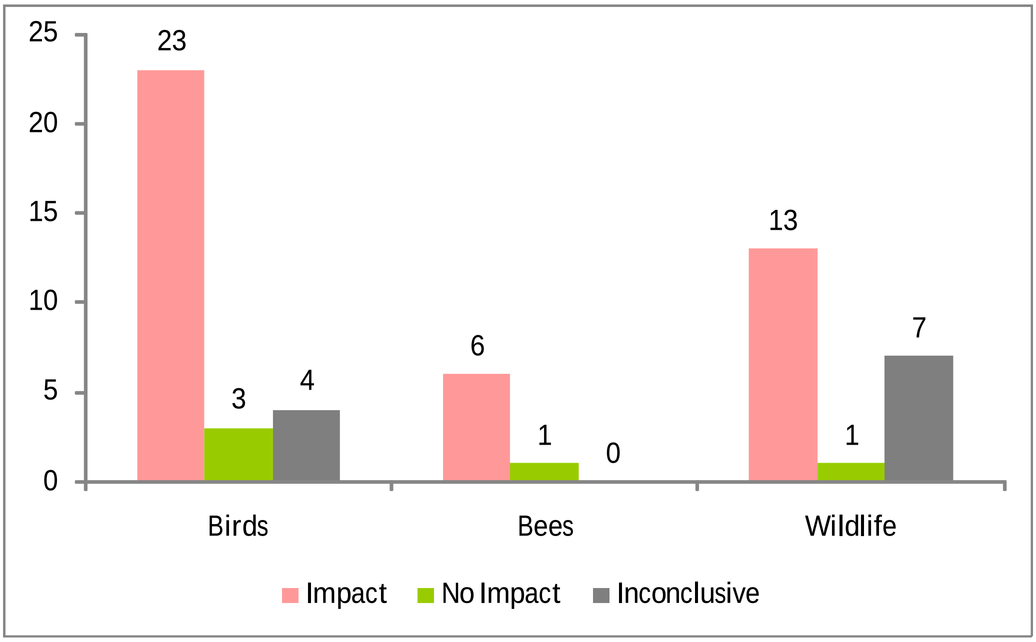


Fig 3. Proportion of study results in Birds, Bees and Wildlife (n=919).

- **TOR II:** ***To assess the likely impacts of the growth in the number of mobile towers in the country.***

India has the second largest population of mobile subscribers in the world and in the absence of any proper policy regulating the construction of mobile towers, the risk of the likely negative impacts of EMF on the health of humans and wildlife is huge. Based on the analysis of the reported studies, the impacts of EMF on different faunal groups were identified, the salient features of which are as discussed below:

Effect on Birds: The earliest reported study on impacts of microwave radiation on birds dates back to 1960s (Tanner, Romero-Sierra, and Davie 1967). In birds, their ability to fly expose them to a greater risk of direct irradiation and hence they appear to be at greater risk as far as effects of EMRs are concerned (Balmori 2005; Balmori and Hallberg 2007; Summers-Smith 2003; Zach and Mayoh 1982; Zach and Mayoh 1984; Zach and Mayoh 1982; Joris and Dirk 2007). Observed effects of exposure to non-ionizing radiation in avian species are mostly from radiation-induced temperature increases (Batellier *et al.* 2008). The incubating avian egg provides a model to study non-thermal effects of microwave exposure since ambient incubation temperature can be adjusted to compensate for absorbed thermal energy. Non-thermal levels of non-ionizing radiation can affect a bird's ability to recover from acute physiological stressors, apart from other potential physiological and behavioural repercussions. Although earlier research indicated that modulated radiofrequency radiation increased calcium-ion efflux in chick forebrain tissue, disagreement on experimental techniques and incongruous results among related studies have

made final conclusions elusive. In an another study, which was carried out by National Research Centre of Canada on interaction of electromagnetic fields and living systems with special reference to birds, it was observed that following the onset of radiation, stabilizing period of the egg production in birds was affected (Bigu, 1973).

Birds have been shown to be able to reliably detect magnetic fields in both the field and laboratory. The rapidly increasing number of cell-phone subscribers is resulting in higher concentration levels of electromagnetic waves in the air, which clashes with the earth's electromagnetic field (Hyland, 2000). Some researchers have reported malformations in chicken embryos exposed to a sinusoidal bipolar oscillating magnetic field (Balmori and Hallberg 2007).

According to a thermal modelling study of a bird subjected to continuous wave (CW) microwave radiation (2.45 GHz), the model predicted that tolerance to microwave radiation for a bird was positively correlated with its mass and that ambient temperature is the environmental variable that has most influence on the level of tolerance for microwave radiation (Byman *et al.* 1986).

Effect on House Sparrows: House Sparrow (*Passer domesticus)* is associated with human habitation and it is one of the indicator species of urban ecosystems. A declining population of the bird provides a warning that the urban ecosystem is experiencing some environmental changes unsuitable for living in the immediate future (Kumar, 2010). London has witnessed a 75 per cent fall in House Sparrow population since 1994, which coincides with the emergence of the cell-phone (Balmori, 2002). Electromagnetic radiation may be responsible, either by itself or in combination with other factors, for the observed decline of the sparrows in European cities (Balmori, 2009, Balmori & Hallberg, 2007). Research in Spain proved that the microwaves released from these towers are harmful to House Sparrows and the increase in the concentration of microwaves results into decrease in House Sparrow populations (Everaert & Bauwen, 2007). Reproductive and co-ordination problems and aggressive behavior has also been observed in birds such as sparrows (Balmori, 2005). General methodology used for such study was, from each area, all sparrows were counted in addition to the mean electric field strength (Everaert & Bauwens, 2007). In similar studies in India, population of *Passer domesticus* was found fast disappearing from areas contaminated with electromagnetic waves arising out of increased number of cell phones, in Bhopal, Nagpur, Jabalpur, Ujjain, Gwaliar, Chhindwara, Indore & Betul (Dongre & Verma, 2009). It was also observed that when 50 eggs of House Sparrow, exposed to electromagnetic radiation (EMR) for durations of five minutes to 30 minutes, all the 50 embryos were found damaged in a study carried out by the Centre for Environment and Vocational Studies of Punjab University (Kumar 2010, Ram 2008).

Male sparrows were seen at locations with relatively high electric field strength values of GSM base stations, providing evidence of how long-term exposure to higher levels of radiation negatively affects the abundance or behavior of House Sparrows in the wild. Thus,

electromagnetic signals are associated with the observed decline in the sparrow population in urban areas.

Effect on White Storks: In monitoring a White Stork (*Ciconia ciconia*) population in Valladolid (Spain) in vicinity of Cellular Phone Base Stations, the results indicated the possibility that microwaves are interfering with the reproduction of White Stork (Balmori, 2010).

Effect of Mobile Radiation on Honey Bees: Many recent studies have linked the electromagnetic radiations with an unusual phenomenon in bees known as 'Colony Collapse Disorder'. Colony Collapse Disorder (CCD) occur when a hive's inhabitants suddenly disappear, leaving only queens, eggs and a few immature workers. The vanished bees are never found, but thought to die solitarily far from home. The theory is that radiation from mobile phones interferes with bees' navigation systems, preventing them from finding their way back to their hives. Even the other animals, parasites and other bees, that normally would raid the honey and pollen left behind when a colony dies, refuse to go anywhere near the abandoned hives. Some scientists believe that CCD is the result of high electromagnetic radiation. As long back as early 1970s, Wellenstein (1973) had reported that the navigational skills of the honey bees were being impacted by high tension lines. In a recent study (Stefan *et al*. 2010) significant differences have been detected in returning of honeybees to their hives: 40% of the non-irradiated bees came back compared to 7.3% of the irradiated ones.

The alarm was first sounded in last autumn, but has now hit half of all American states. The West Coast is thought to have lost 60 per cent of its commercial bee population, with 70 per cent missing on the East Coast. CCD has since spread to Germany, Switzerland, Spain, Portugal, Italy and Greece. John Chapple, one of London's biggest bee-keepers, announced that 23 of his 40 hives have been abruptly abandoned (http://www.independent.co.uk/environment/nature/are-mobile-phones-wiping-out-our-bees-444768.html).

In India, studies conducted by Sainudeen (2011) have proved experimentally that once mobile phones in working condition with frequency of 900 MHz for 10 minutes were kept in the beehives, the worker bees stopped coming to the hives after ten days. He also found drastic decrease in the egg production of queen bees (100 eggs/ day compared to 350 eggs/ day in the control colonies). Earlier studies have also shown (e.g. Greenberg *et al*. 1981) lower eggs being laid in beehives exposed to high voltage transmission lines. Another possible impact of EMR on the bees is the eggs that are exposed to cell phone radiation produce only drones (Brandes and Frish, 1986). Similar studies on a larger scale and better sample size are required in India.

Other wildlife: Phone masts located in the living areas of animals and birds are continuously irradiating some species that could suffer long-term effects, like reduction of their natural defences, deterioration of their health, problems in reproduction and reduction of their useful territory through habitat deterioration. Electromagnetic radiation can exert an aversive

behavioural response in rats, bats and birds such as sparrows. Therefore microwave and radiofrequency pollution constitutes a potential cause for the decline of animal populations and deterioration of health of plants living near phone masts (Balmori, 2005).

Arguably, the most serious concern about the impact of EMF on the living systems appears to be its long term effects on genes and reproductive fitness of species. Today, there is evidence that Electromagnetic Radiation is genotoxic (Blaasaas, Tynes, and Lie 2003; Joris and Dirk 2007; Pourlis 2009; Cherry 2000). An experiment on Common Frog (*Rana temporalis,* new name *Hylarana temporalis*) indicated that radiation emitted by phone masts in a real-time situation may affect the development and may cause rise in mortality of exposed tadpoles. This research may have huge implications for the natural world, which is now exposed to high microwave radiation levels from a multitude of phone masts (Balmori 2010). However, it requires long-term monitoring studies for establishing any causative link between reproductive fitness and EMFs and such data is presently lacking. Moreover, available short term studies are grossly inadequate. For instance a recent review that analysed the literature (till 2001) on the effects of EMF associated with mobile telephony on the prenatal and postnatal development of vertebrates reported that the majority of the studies examined indicated no strong impact on the animal reproduction and development (Pourlis 2009).

Effect on bats: Activity of bats seems to be much reduced in areas with Electro-magnetic fields with densities more than 2V/m (Balmori, 2009). Based on this fact it was recommended to use EMR to repel bats from wind farms (Nicholls and Racey, 2007). In another study in a Free-tailed bat colony (*Tadarida teniotis*) the number of bats decreased when several phone masts were placed 80m from the colony (Balmori *et al*., 2007).

- **TOR III: *To suggest possible mitigatory measures***

Decision was taken in the first and second meetings of the Expert Group to study all peer reviewed articles/ journals published on the impact of radiations on wildlife and to compile the list of the measures taken throughout the world to mitigate the effects of radiations on wildlife including birds and bees. Hence, the standards and exposure limits of radio frequency of different countries were studied in this regard.

Various organizations and countries have developed standards for exposure to radio frequency energy as discussed above. Some countries have established new, low-intensity based exposure standards that respond to studies reporting effects that do not rely only on heating. Currently, the World Health Organization is working to provide a framework for international harmonization of RF safety standards.

Emerging scientific evidence has encouraged some countries to respond by adopting planning targets, or interim action levels that are responsive to low-intensity or non-thermal radiofrequency radiation bio effects and health impacts. It is the WHO’s view that scientific

assessments of risk and science-based exposure limits should not be undermined by the adoption of arbitrary cautionary approaches. Therefore, throughout the world there has been a growing movement to adopt a precautionary approach.

- **TOR IV:** ***To formulate guidelines for regulating the large-scale installation of mobile towers in the country***

With the rapid growth of the mobile industry in India, mobile towers are being built in a haphazard manner without any prior planning and regulation. Hence in view of this, along with lack of any policy controlling the construction of such mobile towers, one of the main tasks of the committee is to formulate guidelines to regulate their installation. At the first meeting of the Expert Committee held on 09.2010, it was decided that few members of the Expert Group will participate in the meeting of the Inter-Ministerial Committee on EMF Radiation held in Ministry of Telecommunications on 06.12.2010, to share the concerns on human as well as wildlife health and to devise a common set of guidelines for mobile towers in the country. The minutes of the meeting was submitted to the Ministry.

- **TOR V:** ***To identify the gap areas for conducting further detailed research***

At the first meeting of the committee, all the members had agreed that the research in India on this issue is very scanty and much research has to be done in this field especially on birds and bees, as well as to find solutions to this issue. Hence, in the second meeting of the Expert Group held on 14.02.2011, a decision was taken to identify the gap areas in research on the issue of impact of radiations on wildlife including birds and bees.

Gap areas for research: Ample information on the impact of EMF on human health is available. However these results cannot be extrapolated to reflect impacts on wildlife impacts since the impact highly varies even within same species depending on multiple factors such as body size, age, earthing, fat content in the body, objects in the immediate vicinity and so on.

Not much data is also available on biological impacts on wild species except for a few species like sparrows and bees. Even this little available information is not reflective of the impact of present background levels of radiation. Information on effects with regards to specific frequencies and species response is lacking. Data on navigation and seasonal migrations as indicated by studies on homing pigeons (Kirchwink 1982) are lacking from the Indian context.

The current ICNIRP guidelines on EMF are developed based especially on laboratory studies, epidemiological data on humans, occupational exposures, in-vitro investigations, observations on cellular changes under control conditions etc. Ecological issues appear to be hardly taken care of. One needs to acknowledge that laboratory observations need not necessarily reflect field effects. Therefore we have to re-visit the guidelines taking account low level electro-smog on wild species especially birds, bees, amphibians etc and modify them accordingly. Our guidelines need to be refined since the ICNIRP Standard currently followed in India is coined

based on only thermal impact of RF and is dismissive of current epidemiological evidence on impacts of non-thermal nature on chronic exposure from multiple towers. The limit on whole-body average SAR is 0.08 W/kg. It is a long way to go before we can have the required long-term 'Species specific data' to decide on the threshold exposure levels for various wildlife species. Till such time a **precautionary principle approach to be used to minimize the exposure levels and we may have to move ahead and adopt stricter norms followed in some other countries like Russia, China, New Zealand etc.**

Since EMF being an invisible form of pollution there needs to be an independent system for monitoring of EMF pollution across the country.

The EMF pollution has reportedly caused population declines on sparrows and bees (causing disorientation and Colony Collapse Disorder (CCD). It has also resulted in aversive behaviour in bats and sparrows, abnormal behaviour in Tits, Kestrels, reproductive failure in White Storks and also fatal bird collisions with involving communication towers causing the death of several million birds of 230 species each year in the USA alone. However, sound scientific investigations in this regard are lacking in India and such studies needs to be undertaken on an urgent basis.

The following areas for specific studies are suggested to be taken up:

- Field studies on impact of cell towers on bee colonies and apiculture,
- Bird/bat/insect mortalities at mobile phone towers with special reference to towers along bird migratory paths,
- Studies on birds / bats / bees to find the effect of EMR on their communication, orientation and co-ordination
- Effect of EMF on amphibian metamorphosis and sex determination in reptiles
- Laboratory studies to develop an understanding on certain species, on their physiological and behavioural aspects, making use of the techniques of bioassay/bio-monitoring
- Measurement, monitoring and mapping of background EMF levels and power density across India involving independent research agencies.
- Regulations/standards to include the ecological characteristics of an area while determining the location of transmission towers, relay stations etc
- Regulations to control installation of transmission towers in human residences/hospitals/dense habitations
- Conduct ecological impact assessment of transmission towers and base stations, with standardised protocols/parameters

Future Scenario

India is one of the fastest growing mobile telephony industries in the world. It is estimated that by 2013, 1 billion plus people will be having cell phone connection in India. With the growth of cell phone subscriber, it has also lead to growth of infrastructure in the form of mobile phone towers. Today, in absence of any policy on infrastructure development and location of cell phone towers, large number of mobile phone towers are being installed in a haphazard manner across urban and sub urban habitats in India.

Along with the growth of phone towers and subscribers, India is also witnessing a rapid population growth. To feed and support this rapidly growing population the agricultural security and the factors influencing them should be of concern. However, the population of many species such as honey bees, which is one of the most important pollinator and important factor for agricultural productivity, has seen a drastic population drop.

Precautionary approach

Throughout the world there has been a growing movement to adopt a precautionary approach. The WHO defines the Precautionary Principle as a risk management concept that provides a flexible approach to identify and manage possible adverse consequences to human health even when it has not been established that the activity or exposure constitutes harm to health.

It is the WHO's view that scientific assessments of risk and science-based exposure limits should not be undermined by the adoption of arbitrary cautionary approaches. The compliance of mobile phone networks and handsets with the ACMA regulations is regarded as a prudent and cautious approach to ensure that the community is not adversely affected by, but benefits from developments in communications.

The Department Of Telecom has constituted an Inter-Ministerial Committee to examine the effect of EMF Radiation on health. The report of the committee is placed in DOT website. The IMC report is under examination of DOT at present.

Recommendations

Following recommendations have been put forward by few members of the Committee:

1) EMF should be recognised as a pollutants/ regular auditing of EMF should be conducted in urban localities/educational/hospital/industrial/residential/recreational premises and around the protected areas and ecologically sensitive areas.
2) Introduce a law for protection of urban flora and fauna from emerging threats like ERM/EMF as conservation issues in urban areas are different from forested or wildlife habitats.
3) Bold signs and messages on the dangers of Cell phone tower and radiation which is emitted from it are displayed in and around the structures where the towers are erected. Use visual daytime markers in areas of high diurnal raptor or waterfowl movements.
4) To avoid bird hits, security lighting for on-ground facilities should be minimized and point downwards or be down-shielded.
5) Independent monitoring of radiation levels and overall health of the community and nature surrounding towers is necessary to identify hazards early.Access to tower sites should be allowed for monitoring radiation levels and animal mortality, if any.
6) Procedure for removal of existing problematic mobile towers should be made easy, particularly in and around protected area or urban parks and centres having wildlife .
7) Strictly control installation of mobile towers near wildlife protected areas, Important Bird Areas, Ramsar Sites, turtle breeding areas, bee colonies, zoos, etc up to a certain distance that should be studied before deciding and should also be practical. Ecological assessment / review of sites identified for installing towers before their installation also may be considered in wildlife / ecologically / conservational important areas.
8) The locations of Cell phone towers and other EMF radiating towers along with their frequencies should be made available on public domain. This can be at city/ district/ village level. Location wise GIS mapping of all cell phone towers be done by DoT. This information will help in monitoring the population of birds and bees in and around the mobile towers and also in and/or around wildlife protected areas.
9) Public consultation to be made mandatory before installation of cell phones towers in any area. The Forest Department should be consulted before installation of cell phone towers in and around PAs and zoos. The distance at which these towers should be installed should be studied case by case basis.
10) Awareness drive with high level of visibility in all forms of media and regional languages should be undertaken by the Government to make people aware about various norms in regard to cell phone towers and dangers from EMR. Such notices should be placed in all wildlife protected areas and in zoos.
11) To prevent overlapping high radiations fields, new towers should not be permitted within a radius of one kilometer of existing towers.

12) If new towers must be built, construct them to be above 80 ft and below 199 ft. tall to avoid the requirement for aviation safety lighting. Construct unguyed towers with platforms that will accommodate possible future co-locations and build them at existing ‘antenna farms’, away from areas of high migratory bird traffic, wetlands and other known bird areas.

Note: Many of the above recommendations have already been given by Government of Delhi and West Bengal (appendix III). The Supreme Court of India has sought explanation from all mobile phone operators and various government and semi-government agencies over the issue of alleged “illegal” and unregulated constructions of mobile phone towers on top of buildings across the country (see www.thehindubusinessline.in/2005/09/27/stories/2005092703950900.htm). Similarly, recent rulings in June 2011 by Punjab and Haryana High Courts also direct the government to inform public about the health hazards (www.indianexpress.com/news/Inform/public/about/health/hazards/of/mobile/tower//HC-to-Govt/800786/).

Conclusion

The review of existing literature shows that the EMRs are interfering with the biological systems in more ways than one and there had already been some warning bells sounded in the case on bees (Warnke 2007; vanEngelsdorp *et al.* 2010; Gould 1980; Sharma and Neelima R Kumar 2010) and birds, which probably heralds the seriousness of this issue and indicates the vulnerability of other species as well. Despite a few reassuring reports (Galloni *et al.* 2005), a vast majority of published literature indicate deleterious effects of EMFs in various species. The window of frequency range and exposure time required to make measurable impacts would vary widely among species and unfortunately we do not have any such data available for most of our free-living floral and faunal species in India. There is an urgent need to focus more scientific attention to this area before it would be too late.

Microwave and radiofrequency pollution appears to constitute a potential cause for the decline of animal populations (Balmori 2006; Balmori and Hallberg 2007; Balmori Martínez 2003; Joris and Dirk 2007; Summers-Smith 2003) and deterioration of health of plants and humans living near radiation sources such as phone masts. Studies have indicated the significant non-thermal long-term impacts of EMFs on species, especially at genetic level which can lead to various health complications including brain tumours (glioma), reduction in sperm counts and sperm mobility, congenital deformities, Psychiatric problems (stress, ‘ringxity’, sleep disorders, memory loss etc.) and endocrine disruptions. However similar aspects are yet to be studied among animal populations.

Pollution from EMRs being a relatively new environmental issue, there is a lack of established standard procedures and protocols to study and monitor the EMF impacts especially

among wildlife, which often make the comparative evaluations between studies difficult. Moreover, there are no long-term data available on the environmental impacts of EMRs as of now. Well-designed long-term impact assessment studies would be required to monitor the impact of ever-increasing intensities of EMRs on our biological environment. Meanwhile the precautionary principle should prevail and we need to better our standards on EMF to match the best in the world.

Studies on impact of Cell phone tower radiation on Birds and wildlife are almost non-existent from India. There is an urgent need for taking up well designed studies to look into this aspect. Available information from the country on the subject of EMF impacts is restricted to few reports from honey-bees. However, these studies are not representative of the real life situations or natural levels of EMF exposure. More studies need to be taken up to scientifically establish if any, the link between the observed abnormalities and disorders in bee hives such as Colony Collapse Disorder (CCD).

Appendices

Appendix I: Photographs showing mobile towers

Appendix II: Precuationary boards about mobile towers

Appendix III: GRs of Delhi and West Bengal Governments

Appendix IV: Bibliography

Members of the Expert Committee

1. Dr. Asad Rahmani, Director, BNHS (Chairman)
2. Representative of Wildlife Institute of India (Dr. Dhananjai Mohan, Dr. B.C. Choudhary)
3. Representative of Deptt. of Telecommunications, New Delhi [Shri. P. K. Panigrahi, Sr. DDG (BW)]
4. Representative of the Centre for Environment & Vocational Studies, Punjab University
5. Representatives of WWF India (Gp Captain Naresh Kapalia, Dr. Parikshit Gautam)
6. Representative of Indian Institute of Science, Bangalore (Prof. H.S. Jamadagni)
7. Representative of Indian Institute of Technology, New Delhi (Prof. R.K. Patney, Deptt. of Electrical Engineering)
8. Representative of SACON (Dr. P.A. Azeez, Director, Dr. Arun Kumar)
9. Dr. Sainuddin Pattazhy, Associate Professor, Deptt. of Zoology, University of Kerala
10. Ms. Prakriti Srivastava, DIG(WL), MoEF (Member Secretary)

Appendix I

Cell phone Towers on commercial and residential Structures

Cell Phone Tower

Cell Phone towers near Keoladeo National Park, Bharatpur, Rajasthan

Appendix II

Precautionary Boards (Some samples)

AREA DEMARCATION

CAUTION

RADIOFREQUENCY RADIATION

- Area of Unrestricted Occupancy
- Minor Injury Possible from Misuse

WARNING

RADIOFREQUENCY RADIATION

- Area of Restricted Occupancy (RF Workers Only)
- Serious Injury Possible from Misuse

DANGER

RADIOFREQUENCY RADIATION

- Area of Denied Occupancy
- Critical Injury or Death Possible

Appendix III

Delhi Government

Vivek Rae
Principal Secretary (Health & FW)

141 / Exposure of Electromagnetic/
D.O.No. PS secy hfw /133-141/
Dated 10/01/2008

Dear

The existing guidelines for granting permission for installation of towers on ground/roof tops for Cellular Mobile Phone Services finalized pursuant to a meeting held at Raj Niwas on 26.7.2002 have been reviewed on the basis of certain representations from the public and it has been decided that henceforth such towers in residential areas should be permitted only in consultation with the concerned Resident Welfare Associations and not left to bilateral negotiations between Telecom companies and individual residents/house owners. In this regard the following additional precautionary measures are also recommended for adoption by the local authorities:

* Installation of Base Station Antennas within the premises of schools and hospitals may be avoided because children and patients are more susceptible to Electro Magnetic Field.

* Installation of Base Station Antennas in narrow lanes should be avoided in order to reduce the risks caused by any earth quake or wind related disaster.

* The Base Station Antennas should be at least 3 m away from the nearby building and antennas should not directly face the building. Further, the lower end of the antenna should be at least 3 meter above the ground or roof.

* In case of multiple transmitter sites at a specific locality sharing of a common tower infrastructure, should be explored, as far as possible, which can be coordinated through a nodal agency.

* Access to Base Station Antenna sites should be prohibited for general public by suitable means such as wire fencing, locking of the door to the roof etc. Access to tower site, even for the maintenance personnel, should be for a minimum period as far as possible.

* Sign boards/Warning Signs are to be provided at Base Station Antenna sites which should be clearly visible and identifiable. A warning sign should be placed at the entrance of such zone.

Contd....2/-

41708181

* The "Warning Sign" should discourage longer stay in the zone, even for the maintenance personnel. The sign board may contain the following text:

  j. Danger! RF radiations, Do not enter!
  ii. Restricted Area

* The operators and maintenance personnel, who are dealing with radio frequency devices, specially with Base Station Antennas installed on towers and at any other outdoor sites, should be protected from electromagnetic radiations. It is required that operators and maintenance personnel should be educated for possible hazards from these devices.

This issues with the approval of LG.

With regards,

Yours sincerely,

(Vivek Rae)

To

1. Shri Ashok Nigam, Commissioner, MCD, Delhi
2. Shri Dinesh Rai, VC, DDA, Delhi
3. Shri Parimal Rai, Chairperson, NDMC, New Delhi

Copy to the following:

1. Principal Secretary to LG, Raj Niwas, Delhi.
2. Principal Secretary to CM, Delhi
3 Pr.Secretary(Urban Development), GNCT of Delhi
4 Secretary (Environment), Govt. of NCT of Delhi, Delhi.
5 Shri T.V.Ramachandran, Director General, Cellular Operators Association of India, 14, Bhai Veer Singh Marg, New Delhi-01.
6 Shri S.C.Khanna, Secretary General, Association of Unified Telecom Service Providers of India, B-601, Gauri Sadan, 5, Hailey Road, New Delhi-01.

(Vivek Rae)

West Bengal Government

In case of non-compliance of the aforementioned directions, regulatory order will be issued in accordance with law.

By Order,
Sd/-
(M. L. Meena)
Principal Secretary,
Department of Environment

No. EN/ 939 /T-IV-1/001/2006 Dated: April 24th., 2008.

Copy forwarded to :-

1. The Incharge, M/s. Bharti Mobitel Limited (Airtel), Infinity Building, 5th. Floor, Salt Lake Electronics Complex, Bidhannagar, Block G.P. Sector-V, Kolkata-700091.
2. The Incharge, Vodafone Essar East Limited (Vodafone), Constantia Office Complex, 4th. Floor, 11, Dr. U.N. Brahmachari Road, Kolkata-700017.
3. The Incharge, Aircel Business Solutions (Aircel), Benfish Bhavan, No. 31, GN Block, 5th. Floor, Sector-V, Salt Lake, Kolkata-700 091.
4. The Incharge, Tata Teleservices Limited (Tata Indicom), C/o. Videsh Sanchar Bhawan, Camp Office- 1/18, C.I.T. Scheme, VII M, Ultandaga, Kolkata-700054.
5. The Incharge, Bharat Sanchar Nigam Limited (BSNL Mobile), Telephone Kendra, P-10, New CIT Road, Kolkata-700073.
6. The Chairman, West Bengal Pollution Control Board.
7. The Member-Secretary, Central Pollution Control Board, Paribesh Bhawan, CBD-cum-Office Complex, East Arjun Nagar, Delhi-110032.
8. The Chief Environment Officer, Department of Environment, Govt. of West Bengal.
9. The Member-Secretary, West Bengal Pollution Control Board, 'Paribesh Bhawan', Salt Lake City, Kolkata-700098.
10. The Commissioner, Kolkata Municipal Corporation, 5, S.N. Banerjee Road, Kolkata-700013.
11. The Commissioner, Howrah Municipal Corporation, Howrah.
12. The Chief Executive Officer, ____________________
13. The Executive Officer, ____________________
14. The Secretary, ...Zilla Parishad.

with a request to circulate this memo. to the Panchayats for information and necessary action.

15. The District Magistrate____________________

Sd/-

HENCE, in exercise of the powers conferred under Environment (Protection) Act, 1986 and rules made thereunder, all mobile phone service providers are hereby directed to follow the following guidelines strictly at the time of installation of the mobile towers.

- Installation of Base Station Antennas within the premises of schools and hospitals may be avoided because children and patients are more susceptible to Electro Magnetic Field.
- Installation of Base Station Antennas in narrow lanes should be avoided in order to reduce the risks caused by any earth quake or wind related disaster.
- The Base Station Antennas should be at least 3 m away from the nearby building and antennas should not directly face the building. Further, the lower end of the antenna should be at least 3 metre above the ground or roof.
- In case of multiple transmitter sites at a specific locality sharing of a common tower infrastructure, should be explored, as far as possible, which can be coordinated through a nodal agency.
- Access to Base Station Antenna sites should be prohibited for general public by suitable means such as wire fencing, locking of the door to the roof etc. Access to tower site, even for the maintenance personnel, should be for a minimum period as far as possible.
- Sign boards/Warning Signs are to be provided at Base Station Antenna sites which should be clearly visible and identifiable. A warning sign should be placed at the entrance of such zone.
- The "Warning Sign" should discourage longer stay in the zone, even for the maintenance personnel. The sign board may contain the following text :

  i. Danger ! RF radiations, Do not enter !
  ii. Restricted Area.

The operators and maintenance personnel, who are dealing with radio frequency devices, specially with Base Station Antennas installed on towers and at any other outdoor sites, should be protected from electromagnetic radiations. It is required that operators and maintenance personnel should be educated for possible hazards from these devices.

All local authorities are also requested that before giving any permission for installation of the mobile towers aforementioned guidelines should be

Appendix IV

Bibliography

List of Scientific Papers (n=919) on Impact of EMFs classified Subject-wise
Each bibliographic entry is marked with category codes in squire brackets []

B= Birds; E= Bees; H = Humans; W= Animals/Wildlife; P= Plants
+ = Impact reported; - = No Impact; * = Inconclusive/ Impact not evaluated

Aalto, S. et al, (2006) Mobile phone affects cerebral blood flow in humans, J Cereb Blood Flow Metab. 2006 Jul;26(7):885-90. [H+]

Abdel-Rassoul, G. et al. (2007) Neurobehavioral effects among inhabitants around mobile phone base stations, Neurotoxicology. 28(2):434-40. [H+]

Abdus-salam, A. et al. (2008) Mobile phone radiation and the risk of cancer; a review, Afr J Med Med Sci. 2008 37(2):107-18. [H-]

Abramson, MJ et al. (2009) Mobile telephone use is associated with changes in cognitive function in young adolescents, Bioelectromagnetics. 30: [E-pub ahead of print]. [H+]

Adey, W.R. (1993) Biological effects of electromagnetic fields. Journal of Cellular Biochemistry. 51:410–410. [H+]

Agarwal, A. et al, (January 2008) Effect of cell phone usage on semen analysis in men attending infertility clinic, Fertil Steril. 2008 Jan;89(1):124-8. [H+]

Agarwal, A. et al. (September 2008) Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: an in vitro pilot study, Fertil Steril. 2008 Sep 18. [E-publication]. [Vi [H+]

Agarwal, A., Deepinder, F., Sharma, R.K., Ranga, G. & Li, J. (2008) Effect of cell phone usage on semen analysis in men attending infertility clinic: an observational study. Fertility and sterility. 89: 124–128. [H+]

Ahlbom A et al, (December 2001) Review of the epidemiologic literature on EMF and Health, Environ Health Perspect. 2001 Dec;109 Suppl 6:911-33. [H+]

Ahlbom A et al, (September 2000) A pooled analysis of magnetic fields and childhood leukaemia, Br J Cancer. 2000 Sep;83(5):692-8. [H+]

Ahlbom A et al, (September 2009) Epidemiologic evidence on mobile phones and tumor risk: a review, Epidemiology. 2009 Sep;20(5):639-52. [H-]

Ahlbom A, (2001) Neurodegenerative diseases, suicide and depressive symptoms in relation to EMF, Bioelectromagnetics. 2001;Suppl 5:S132-43. [H+]

Ainsbury EA et al, (July 2005) An investigation into the vector ellipticity of extremely low frequency magnetic fields from appliances in UK homes, Phys Med Biol. 2005 Jul 7;50(13):3197-209. [H*]

Akdag MZ et al, (February 2010) Effects of Extremely Low-Frequency Magnetic Field on Caspase Activities and Oxidative Stress Values in Rat Brain, Biol Trace Elem Res. 2010 Feb 23. [Epub ahead of print]. [View on Pubmed [H-]

Akdag MZ et al, (June 2010) The effect of long-term extremely low-frequency magnetic field on geometric and biomechanical properties of rats' bone, Electromagn Biol Med. 2010 Jun;29(1-2):9-18. [H+]

Al-Akhras MA et al, (2008) Influence of 50 Hz magnetic field on sex hormones and body, uterine, and ovarian weights of adult female rats, Electromagn Biol Med. 2008;27(2):155-63. [H+]

Alasdair. Positive Effects of EMFs. [H-]

Albanese A et al, (2009) Alterations in adenylate kinase activity in human PBMCs after in vitro exposure to electromagnetic field: comparison between extremely low frequency electromagnetic field (ELF) and therapeutic application of a musicall [H+]

Al-Khlaiwi T, Meo SA, (June 2004) Association of mobile phone radiation with fatigue, headache, dizziness, tension and sleep disturbance in Saudi population, Saudi Med J. 2004 Jun;25(6):732-6. [H+]

Altpeter ES et al, (February 2006) Effect of short-wave (6-22 MHz) magnetic fields on sleep quality and melatonin cycle in humans: the Schwarzenburg shut-down study, Bioelectromagnetics. 2006 Feb;27(2):142-50. [View on [H+]

Aly AA et al, (February 2008) Effects of 900-MHz radio frequencies on the chemotaxis of human neutrophils in vitro, IEEE Trans Biomed Eng. 2008 Feb;55(2):795-7. [H+]

Andel R et al, (November 2010) Work-related exposure to extremely low-frequency magnetic fields and dementia: results from the population-based study of dementia in Swedish twins, J Gerontol A Biol Sci Med Sci. 2010 Nov;65(11):1220-7. Epub 201 [H+]

Anderson LE et al, (August 1999) Effect of 13 week magnetic field exposures on DMBA-initiated mammary gland carcinomas in female Sprague-Dawley rats, Carcinogenesis. 1999 Aug;20(8):1615-20. [W-]

Anderson LE et al, (September 2000) Effects of 50- or 60-hertz, 100 microT magnetic field exposure in the DMBA mammary cancer model in Sprague-Dawley rats: possible explanations for different results from two laboratories, Environ Health Persp [W*]

Andrzejak R et al, (August 2008) The influence of the call with a mobile phone on heart rate variability parameters in healthy volunteers, Ind Health. 2008 Aug;46(4):409-17. [H+]

Arendash GW et al, (January 2010) Electromagnetic field treatment protects against and reverses cognitive impairment in Alzheimer's disease mice, J Alzheimers Dis. 2010 Jan;19(1):191-210. [W+]

Arnetz BB et al, (2007) The Effects of 884 MHz GSM Wireless Communication Signals on Self-reported Symptom and Sleep (EEG)- An Experimental Provocation Study, PIERS Online Vol. 3 No. 7 2007 pp: 1148-1150. [H+]

Atay, T., Aksoy, B.A., Aydogan, N.H., Baydar, M.L., Yildiz, M. & Ozdemir, R. (2009) Effect of electromagnetic field induced by radio frequency waves at 900 to 1800 MHz on bone mineral density of iliac bone wings. The Journal of Craniofacial Surgery, 20, 1556-1560. [H+]

Auger N et al, (July 2010) The relationship between residential proximity to extremely low frequency power transmission lines and adverse birth outcomes, J Epidemiol Community Health. 2010 Jul 13. [Epub ahead of print] [View Comments and Links [H-]

Augner C et al, (September 2008) GSM base stations: Short-term effects on well-being, Bioelectromagnetics. 2008 Sep 19. [Epub ahead of print]. [H+]

Auvinen A et al, (May 2002) Brain tumors and salivary gland cancers among cellular telephone users, Epidemiology. 2002 May;13(3):356-9. [H*]

Bachmann M et al, (2006) Integration of differences in EEG Analysis Reveals Changes in Human EEG Caused by Microwave, Conf Proc IEEE Eng Med Biol Soc. 2006;1:1597-600. [H+]

Balik HH et al, (March 2005) Some ocular symptoms and sensations experienced by long term users of mobile phones, Pathol Biol (Paris). 2005 Mar;53(2):88-91. [H+]

Balmori A, (March 2009) Electromagnetic pollution from phone masts. Effects on wildlife, Pathophysiology. 2009 Mar 3. [Epub ahead of print]. [W+]

Balmori A, (October 2005) Possible Effects of Electromagnetic Fields from Phone Masts on a Population of White Stork (Ciconia ciconia), Electromagn Biol Med 24: 109-119, 2005. [B+]

Balmori Martínez, A. (2003) The effects of microwaves on the trees and other plants. Valladolid, Spain, 2003b. Available online at buergerwelle. de. [P+]

Balmori, A. & Hallberg, Ö. (2007) The urban decline of the house sparrow (Passer domesticus): a possible link with electromagnetic radiation. Electromagnetic biology and medicine, 26, 141–151. [B+]

Balmori, A. (2005) Possible effects of electromagnetic fields from phone masts on a population of white stork (Ciconia ciconia). Electromagnetic Biology and Medicine, 24, 109–119. [B+]

Balmori, A. (2006) The incidence of electromagnetic pollution on the amphibian decline: Is this an important piece of the puzzle? Toxicological and Environmental Chemistry, 88, 287–299. [W+]

Balmori, A. (2009) Electromagnetic pollution from phone masts. Effects on wildlife. Pathophysiology, 16, 191–199. [W+]

Baris D et al, (January 1996) A case cohort study of suicide in relation to exposure to electric and magnetic fields among electrical utility workers, Occup Environ Med. 1996 Jan;53(1):17-24. [H+]

Barron, H.W., Roberts, R.E., Latimer, K.S., Hernandez-Divers, S. & Northrup, N.C. (2009) Tolerance Doses of Cutaneous and Mucosal Tissues in Ring-necked Parakeets (Psittacula krameri) for External Beam Megavoltage Radiation. Journal of Avian Medicine and Surgery, 23, 6-9. [B+]

Barry, N. & Paul, A.R. (2010) Bats Avoid Radar Installations: Could Electromagnetic Fields Deter Bats from Colliding with Wind Turbines? PLoS ONE, 2, 1-7. [W+]

Barth A et al, (April 2010) Effects of extremely low-frequency magnetic field exposure on cognitive functions: results of a meta-analysis, Bioelectromagnetics. 2010 Apr;31(3):173-9. [H-]

Bas O et al, (February 2009) 900 MHz electromagnetic field exposure affects qualitative and quantitative features of hippocampal pyramidal cells in the adult female rat, Brain Res. 2009 Feb 20. [Epub ahead of print]. [[W+]

Baste V et al, (April 2008) Radiofrequency electromagnetic fields; male infertility and sex ratio of offspring, Eur J Epidemiol. 2008 Apr 16 [Epub ahead of print]. [H+]

Baste V et al, (January 2010) Radiofrequency exposure on fast patrol boats in the Royal Norwegian Navy-an approach to a dose assessment, Bioelectromagnetics. 2010 Jan 6. [Epub [H*]

Batellier, F., Couty, I., Picard, D. & Brillard, J.P. (2008) Effects of exposing chicken eggs to a cell phone in "call" position over the entire incubation period. Theriogenology, 69, 737–745. [B+]

Beale IL et al, (1997) Psychological effects of chronic exposure to 50 Hz magnetic fields in humans living near extra-high-voltage transmission lines, Bioelectromagnetics. 1997;18(8):584-94. [H+]

Beale IL et al, (August 2001) Association Of Health Problems With 50 -Hz Magnetic Fields In Human Adults Living Near Power Transmission Lines, Journal of the Australasian College of Nutritional & Environmental Mediciine, 20(2) August 2001 [Vie [H+]

Beason R, Semm P, (November 2002) Responses of neurons to an amplitude modulated microwave stimulus, Neurosci Lett 2002 Nov 29;333(3):175-8. [H+]

Beason, R.C. & Semm, P. (2002) Responses of neurons to an amplitude modulated microwave stimulus. Neuroscience Letters, 333, 175–178. [H*]

Bediz CS et al, (February 2006) Zinc supplementation ameliorates electromagnetic field-induced lipid peroxidation in the rat brain, Tohoku J Exp Med. 2006 Feb;208(2):133-40. [W+]

Behari, J. (2002) Electromagnetic pollution-the causes and concerns. Electromagnetic Interference and Compatibility, 2001/02. Proceedings of the International Conference on p. 316–320. [H*]

Belyaev I et al, (October 2009) Microwaves from Mobile Phones Inhibit 53BP1 Focus Formation in Human Stem Cells Stronger than in Differentiated Cells: Possible Mechanistic Link to Cancer Risk, Environ Health Perspect. 2009 Oct 22. [Epub ahead [H+]

Belyaev IY et al, (April 2005) 915 MHz microwaves and 50 Hz magnetic field affect chromatin conformation and 53BP1 foci in human lymphocytes from hypersensitive and healthy persons, Bioelectromagnetics. 2005 Apr;26(3):173-84 [View Comments and [H+]

Belyaev IY et al, (May 2006) Exposure of rat brain to 915 MHz GSM microwaves induces changes in gene expression but not double stranded DNA breaks or effects on chromatin conformation, Bioelectromagnetics. 2006 May;27(4):295-306 [View Comments [H+]

Belyaev IY et al, (October 2008) Microwaves from UMTS/GSM mobile phones induce long-lasting inhibition of 53BP1/gamma-H2AX DNA repair foci in human lymphocytes, Bioelectromagnetics. 2008 Oct 6. [Epub ahead of print]. [[H+]

Berg-Beckhoff G et al, (February 2009) Mobile phone base stations and adverse health effects: phase 2 of a cross-sectional study with measured radio frequency electromagnetic fields, Occup Environ Med. 2009 Feb;66(2):124-30 [View Comments and [H-]

Bergdahl J et al, (October 1998) Odontologic survey of referred patients with symptoms allegedly caused by electricity or visual display units, Acta Odontol Scand. 1998 Oct;56(5):303-7. [H*]

Bergeron, N.A. (2008) Electromagnetic Wave Impact on Amphibian Metamorphosis. [W+]

Bernabo N et al, (June 2010) Extremely low frequency electromagnetic field exposure affects fertilization outcome in swine animal model, Theriogenology. 2010 Jun;73(9):1293-305. Epub 2010 Feb 21. [W+]

Bernard N et al, (October 2008) Assessing the Potential Leukemogenic Effects of 50 Hz and their Harmonics Using an Animal Leukemia Model, J Radiat Res (Tokyo). 2008 Oct 4. [Epub ahead of print]. [W-]

Bhattacharjee, D., Ivannikov, A.I., Zhumadilov, K., Stepanenko, V.F., Tanaka, K., Endo, S., Ohtaki, M., Totoda, S., Bhattacharyya, J. & Hoshi, M. (2009) Radiation Dose Measurement by Electron Spin Resonance Studies of Tooth Enamel in Lime and Non-lime Consuming Individuals from the Silchar Region of Northeast India. Journal of radiation research, 50, 559-565. [H*]

Bianchi A, Phillips JG, (February 2005) Psychological predictors of problem mobile phone use, Cyberpsychol Behav. 2005 Feb;8(1):39-51. [H*]

Billaudel B et al, (May 2009) Effects of exposure to DAMPS and GSM signals on Ornithine Decarboxylase (ODC) activity: II- SH-SY5Y human neuroblastoma cells, Int J Radiat Biol. 2009 May 12:1-4. [Epub ahead of print]. [V [H-]

Binhi V, (January 2007) A mathematical model of DNA degradation: possible role of magnetic nanoparticles, arXiv.org - 0701202v1. [H+]

Binhi V, (July 2008) Do naturally occurring magnetic nanoparticles in the human body mediate increased risk of childhood leukaemia with EMF exposure?, Int J Radiat Biol. 2008 Jul;84(7):569-79. [H+]

Binhi V, Chernavskh D, (2005) Stochastic dynamics of magnetosomes in cytoskeleton, Europhysics Letters - 70 (6), pp. 850856 (2005). [H*]

Blaasaas, K.G., Tynes, T. & Lie, R.T. (2003) Residence near power lines and the risk of birth defects. Epidemiology, 14, 95–98. [H+]

Blackman C, (March 2009) Cell phone radiation: Evidence from ELF and RF studies supporting more inclusive risk identification and assessment, Pathophysiology. 2009 Aug;16(2-3):205-16. Epub 2009 Mar 4. [H+]

Blackman C, (March 2009) Cell phone radiation: Evidence from ELF and RF studies supporting more inclusive risk identification and assessment, Pathophysiology. 2009 Aug;16(2-3):205-16. Epub 2009 Mar 4. [H+]

Blackman CF et al, (February 2001) The influence of 1.2 microT, 60 Hz magnetic fields on melatonin- and tamoxifen-induced inhibition of MCF-7 cell growth, Bioelectromagnetics. 2001 Feb;22(2):122-8. [H+]

Blackman CF, (2006) Can EMF exposure during development leave an imprint later in life?, Electromagn Biol Med. 2006;25(4):217-25. [H*]

Blank M, (2008) Protein and DNA reactions stimulated by electromagnetic fields, Electromagn Biol Med. 2008;27(1):3-23. [H+]

Blank M, Goodman R, (March 2009) Electromagnetic fields stress living cells, Pathophysiology. 2009 Mar 4. [Epub ahead of print]. [H+]

Blask DE et al, (December 2005) Melatonin-depleted blood from premenopausal women exposed to light at night stimulates growth of human breast cancer xenografts in nude rats, Cancer Res. 2005 Dec 1;65(23):11174-84. [Vie [H+]

Blettner M et al, (November 2008) Mobile phone base stations and adverse health effects: Phase 1: A population-based cross-sectional study in Germany, Occup Environ Med. 2008 Nov 18. [Epub ahead of print]. [View on Pub [H+]

Boorman GA et al, (May 1999) Effect of 26 week magnetic field exposures in a DMBA initiation-promotion mammary gland model in Sprague-Dawley rats, Carcinogenesis. 1999 May;20(5):899-904. [W-]

Boorman GA et al, (May 2000) Leukemia and lymphoma incidence in rodents exposed to low-frequency magnetic fields, Radiat Res. 2000 May;153(5 Pt 2):627-36. [W-]

Borbely AA et al, (November 1999) Pulsed high-frequency electromagnetic field affects human sleep and sleep electroencephalogram, Neurosci Lett. 1999 Nov 19;275(3):207-10. [H+]

Bortkiewicz A et al, (2004) Subjective symptoms reported by people living in the vicinity of cellular phone base stations: review, Med Pr. 2004;55(4):345-51. [H+]

Bortkiewicz A et al, (July 1996) Heart rate variability in workers exposed to medium-frequency electromagnetic fields, J Auton Nerv Syst. 1996 Jul 5;59(3):91-7. [H+]

Bortkiewicz A et al, (March 1997) Ambulatory ECG monitoring in workers exposed to electromagnetic fields, J Med Eng Technol. 1997 Mar-Apr;21(2):41-6. [H+]

Braune, S., Riedel, A., Schulte-MAnting, J. & Raczek, J. (2002) Influence of a Radiofrequency Electromagnetic Field on Cardiovascular and Hormonal Parameters of the Autonomic Nervous System in Healthy Individuals. Radiation research, 158, 352-356. [H+]

Breckenkamp J et al, (May 2009) Feasibility of a cohort study on health risks caused by occupational exposure to radiofrequency electromagnetic fields, Environ Health. 2009 May 29;8:23. [H*]

Brent, R.L. (1999) Reproductive and teratologic effects of low-frequency electromagnetic fields: A review of in vivo and in vitro studies using animal models. Teratology, 59, 261–286. [H-]

Brent, R.L., Gordon, W.E., Bennett, W.R. & Beckman, D.A. (1993) Reproductive and teratologic effects of electromagnetic fields. Reproductive toxicology, 7, 535–580. [H+]

Brescia F et al, (October 2009) Reactive oxygen species formation is not enhanced by exposure to UMTS 1950 MHz radiation and co-exposure to ferrous ions in Jurkat cells, Bioelectromagnetics. 2009 Oct;30(7):525-35. [Vie [H-]

Bryan, T.E. & Gildersleeve, R.P. (1988) Effects of nonionizing radiation on birds. Comparative Biochemistry and Physiology Part A: Physiology, 89, 511-530. [B+]

Budak GG et al, (April 2009) Effects of GSM-like radiofrequency on distortion product otoacoustic emissions in pregnant adult rabbits, Clin Invest Med. 2009 Apr 1;32(2):E112-6. [W+]

Budak GG et al, (March 2009) Effects of intrauterine and extrauterine exposure to GSM-like radiofrequency on distortion product otoacoustic emissions in infant male rabbits, Int J Pediatr Otorhinolaryngol. 2009 Mar;73(3):391-9. Epub 2008 Dec 2 [W+]

Budi A et al, (December 2005) Electric field effects on insulin chain-B conformation, J Phys Chem B. 2005 Dec 1;109(47):22641-8. [H+]

Budi A et al, (May 2007) Effect of frequency on insulin response to electric field stress, J Phys Chem B. 2007 May 24;111(20):5748-56. [H+]

Burch JB et al, (February 2000) Melatonin metabolite levels in workers exposed to 60-Hz magnetic fields: work in substations and with 3-phase conductors, J Occup Environ Med. 2000 Feb;42(2):136-42. [H+]

Burch JB et al, (July 1999) Reduced excretion of a melatonin metabolite in workers exposed to 60 Hz magnetic fields, Am J Epidemiol. 1999 Jul 1;150(1):27-36. [H*]

Burch JB et al, (June 1998) Nocturnal excretion of a urinary melatonin metabolite among electric utility workers, Scand J Work Environ Health. 1998 Jun;24(3):183-9. [H+]

Burch JB et al, (November 2002) Melatonin metabolite excretion among cellular telephone users, Int J Radiat Biol. 2002 Nov;78(11):1029-36. [H+]

Burda H et al, (April 2009) Extremely low-frequency electromagnetic fields disrupt magnetic alignment of ruminants, Proc Natl Acad Sci U S A. 2009 Apr 7;106(14):5708-13. Epub 2009 Mar 19. [W+]

Burdak-Rothkamm S et al, (November 2008) DNA and chromosomal damage in response to intermittent extremely low-frequency magnetic fields, Mutat Res. 2008 Nov 13. [Epub ahead of print]. [H-]

Byman, D., Demetri, E.P., Wasserman, F.E., Battista, S.P. & Kunz, T.H. (1986) Thermal Modelling of Small Birds Exposed to Microwave Radiation (2· 45 GHz CW). Journal of applied ecology, 23, 449–459. [B+]

California EMF Program, (June 2002) An Evaluation of the Possible Risks From Electric and Magnetic Fields (EMFs) From Power Lines, Internal Wiring, Electrical Occupations and Appliances,. [H+]

Calvente I et al, (July 2010) Exposure to electromagnetic fields (non-ionizing radiation) and its relationship with childhood leukemia: a systematic review, Sci Total Environ. 2010 Jul 15;408(16):3062-9. Epub 2010 May 7 [View Comments and Link [H*]

Campbell, B.A., Jhamb, A., Maguire, J.A., Toyota, B. & Ma, R. (2009) Meningiomas in 2009: controversies and future challenges. American journal of clinical oncology, 32, 73. [H*]

Cano MI, Pollan M, (August 2001) Non-Hodgkin's lymphomas and occupation in Sweden, Int Arch Occup Environ Health. 2001 Aug;74(6):443-9. [H+]

Cao Y et al, (2009) 900-MHz Microwave Radiation Enhances gamma-Ray Adverse Effects on SHG44 Cells, J Toxicol Environ Health A. 2009;72(11-12):727-32. [H+]

Cao YN et al, (August 2006) Effects of exposure to extremely low frequency electromagnetic fields on reproduction of female mice and development of offsprings, Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 2006 Aug;24(8):468-70 [View Comment [W+]

Cao Z et al, (March 2000) Effects of electromagnetic radiation from handsets of cellular telephone on neurobehavioral function, Wei Sheng Yan Jiu. 2000 Mar 30;29(2):102-3. [H+]

Caraglia M et al, (August 2005) Electromagnetic fields at mobile phone frequency induce apoptosis and inactivation of the multi-chaperone complex in human epidermoid cancer cells, J Cell Physiol. 2005 Aug;204(2):539-48 [View Comments and Links [H+]

Cardis E et al, (June 2008) Distribution of RF energy emitted by mobile phones in anatomical structures of the brain, Phys Med Biol. 2008 Jun 7;53(11):2771-83. Epub 2008 May 1. [H*]

Cardis E et al, (June 2010) Brain tumour risk in relation to mobile telephone use: results of the INTERPHONE international case-control study, Int J Epidemiol. 2010 Jun;39(3):675-94. Epub 2010 May 17. [H*]

Carlo, G.L. (2007) The latest reassurance ruse about cell phones and cancer. Journal of the Australasian College of Nutritional & Environmental Medicine-April, 1. [H+]

Carpenter DO et al, (January 2010) Electromagnetic fields and cancer: the cost of doing nothing, Rev Environ Health. 2010 Jan-Mar;25(1):75-80. [H+]

Carrillo-Vico A et al, (February 2005) Human lymphocyte-synthesized melatonin is involved in the regulation of the interleukin-2/interleukin-2 receptor system, J Clin Endocrinol Metab. 2005 Feb;90(2):992-1000. [View on [H*]

Carrubba S et al, (January 2010) Mobile-phone pulse triggers evoked potentials, Neurosci Lett. 2010 Jan 18;469(1):164-8. Epub 2009 Dec 4. [H+]

Cecconi S et al, (November 2000) Evaluation of the effects of extremely low frequency electromagnetic fields on mammalian follicle development, Hum Reprod. 2000 Nov;15(11):2319-25. [W+]

Cech R et al, (February 2007) Fetal exposure to low frequency electric and magnetic fields, Phys Med Biol. 2007 Feb 21;52(4):879-88. [H*]

Celikler S et al, (December 2009) A biomonitoring study of genotoxic risk to workers of transformers and distribution line stations, Int J Environ Health Res. 2009 Dec;19(6):421-30. [H+]

Cellini L et al, (May 2008) Bacterial response to the exposure of 50 Hz electromagnetic fields, Bioelectromagnetics. 2008 May;29(4):302-11. [H+]

Chamberlain, D.E., Toms, M.P., Cleary-McHarg, R. & Banks, A.N. (2007) House sparrow (Passer domesticus) habitat use in urbanized landscapes. Journal of Ornithology, 148, 453–462. [B*]

Chapman, S. (2004) Book Review: Cellular Phones, Public Fears, and a Culture of Precaution. New Media & Society, 6, 835. [H+]

Charles LE et al, (April 2003) Electromagnetic fields, polychlorinated biphenyls, and prostate cancer mortality in electric utility workers, Am J Epidemiol. 2003 Apr 15;157(8):683-91. [H+]

Chen C et al, (February 2010) Extremely low-frequency electromagnetic fields exposure and female breast cancer risk: a meta-analysis based on 24,338 cases and 60,628 controls, Breast Cancer Res Treat. 2010 Feb 10. [Epub ahead of print] [View C [H-]

Cherry, N. (2000) Evidence that Electromagnetic Radiation is Genotoxic: The implications for the epidemiology of cancer and cardiac, neurological and reproductive effects [H+]

Cherry, N. (2003) EMR Reduces Melatonin in Animals and People. Environmental Management and Design Division, 84. [W+]

Chia SE et al, (November 2000) Prevalence of headache among handheld cellular telephone users in Singapore: a community study, Environ Health Perspect. 2000 Nov;108(11):1059-62. [H+]

Chiu RS, Stuchly MA, (June 2005) Electric fields in bone marrow substructures at power-line frequencies, IEEE Trans Biomed Eng. 2005 Jun;52(6):1103-9. [H+]

Cho YH, Chung HW, (June 2003) The effect of extremely low frequency electromagnetic fields (ELF-EMF) on the frequency of micronuclei and sister chromatid exchange in human lymphocytes induced by benzo(a)pyrene, Toxicol Lett. 2003 Jun 5;143(1): [H+]

Chowdary, T.H. (2005) 15, Radio Communications, Mobile Telephony and Regulation in India-Case Study. Asia unplugged: the wireless and mobile media boom in the Asia-Pacific [H*]

Christ A et al, (April 2010) Age-dependent tissue-specific exposure of cell phone users, Phys Med Biol. 2010 Apr 7;55(7):1767-83. Epub 2010 Mar 5. [H*]

Christ A, Kuster N, (2005) Differences in RF energy absorption in the heads of adults and children, Bioelectromagnetics. 2005;Suppl 7:S31-44. [H*]

Christensen HC et al, (April 2005) Cellular telephones and risk for brain tumors: a population-based, incident case-control study, Neurology. 2005 Apr 12;64(7):1189-95 [View [H-]

Christensen HC et al, (February 2004) Cellular telephone use and risk of acoustic neuroma, Am J Epidemiol. 2004 Feb 1;159(3):277-83. [H-]

Cinel C et al, (March 2008) Exposure to Mobile Phone Electromagnetic Fields and Subjective Symptoms: A Double-Blind Study, Psychosom Med. 2008 Mar 31. [H-]

Clapp RW et al, (January 2008) Environmental and occupational causes of cancer: new evidence 2005-2007, Rev Environ Health. 2008 Jan-Mar;23(1):1-37. [H*]

Clark ML et al, (October 2007) Biomonitoring of estrogen and melatonin metabolites among women residing near radio and television broadcasting transmitters, J Occup Environ Med. 2007 Oct;49(10):1149-56. [View on Pubmed [H+]

Cleveland, R.F., Fields, R.E. & Ulcek, J.L. (1999) Questions and answers about biological effects and potential hazards of radiofrequency electromagnetic fields. [H+]

Cohen B et al, (May 1998) Deposition of charged particles on lung airways, Health Phys 74(5):554-60. [H+]

Coleman MP et al, (November 1989) Leukaemia and residence near electricity transmission equipment: a case-control study, Br J Cancer. 1989 Nov;60(5):793-8. [H+]

Comba P, Fazzo L, (2009) Health effects of magnetic fields generated from power lines: new clues for an old puzzle, Ann Ist Super Sanita. 2009;45(3):233-7. [H+]

Contalbrigo L et al, (August 2009) Effects of different electromagnetic fields on circadian rhythms of some haematochemical parameters in rats, Biomed Environ Sci. 2009 Aug;22(4):348-53. [W+]

Contalbrigo L et al, (August 2009) Effects of different electromagnetic fields on circadian rhythms of some haematochemical parameters in rats, Biomed Environ Sci. 2009 Aug;22(4):348-53. [W+]

Cook A et al, (June 2003) Cellular telephone use and time trends for brain, head and neck tumours, N Z Med J. 2003 Jun 6;116(1175):U457. [H-]

Cook CM et al, (July 2008) Changes in human EEG alpha activity following exposure to two different pulsed magnetic field sequences, Bioelectromagnetics. 2008 Jul 28 [Epub]. [H+]

Copplestone, D., Howard, B.J. & Brachignac, F. (2004) The ecological relevance of current approaches for environmental protection from exposure to ionising radiation. Journal of Environmental Radioactivity, 74, 31-41. [H*]

Copplestone, D., Wood, M.D., Merrill, P.C., Allott, R., Jones, S.R., i Batlle, J.V., Beresford, N.A. & Zinger, I. (2005) Impact assessment of ionising radiation on wildlife: Meeting the requirements of the EU birds and habitats directives. Radioprotection, 40, 893–898. [W*]

Coulton LA, Barker AT, (March 2003) Magnetic fields and intracellular calcium: effects on lymphocytes exposed to conditions for 'cyclotron resonance', Phys Med Biol. 1993 Mar;38(3):347-60. [H-]

Croft RJ et al, (December 2008) Mobile phones and brain tumours: a review of epidemiological research, Australas Phys Eng Sci Med. 2008 Dec;31(4):255-67. [H*]

Crumpton MJ, (June 2005) The Bernal Lecture 2004 Are low-frequency electromagnetic fields a health hazard?, Philos Trans R Soc Lond B Biol Sci. 2005 Jun 29;360(1458):1223-30. [H*]

Crumpton MJ, Collins AR, (October 2004) Are environmental electromagnetic fields genotoxic?, DNA Repair (Amst). 2004 Oct 5;3(10):1385-7. [H*]

Cvetkovic D, Cosic I, (October 2009) Alterations of human electroencephalographic activity caused by multiple extremely low frequency magnetic field exposures, Med Biol Eng Comput. 2009 Oct;47(10):1063-73. Epub 2009 Aug 26 [View Comments and L [H+]

Czyz J et al, (May 2004) High frequency electromagnetic fields (GSM signals) affect gene expression levels in tumor suppressor p53-deficient embryonic stem cells, Bioelectromagnetics. 2004 May;25(4):296-307. [View on P [H+]

D.C. Gupta. (2007) Microwave and EMR Pollution (Due to Mobile Towers and Mobile Phones. Procedings of Fifth International Conference on Dynamic Systems and Applications p. May 30 - June 2, 2007 Morehouse College Atlanta, Georgia, USA. [H+]

Dahmen N et al, (March 2009) Blood laboratory findings in patients suffering from self-perceived electromagnetic hypersensitivity (EHS), Bioelectromagnetics. 2009 Mar [H*]

D'Ambrosio G et al, (January 2002) Cytogenetic damage in human lymphocytes following GMSK phase modulated microwave exposure, Bioelectromagnetics. 2002 Jan;23(1):7-13. [H+]

Daniells C et al, (March 1998) Transgenic nematodes as biomonitors of microwave-induced stress, Mutat Res. 1998 Mar 13;399(1):55-64. [H+]

Davanipour Z, Sobel E, (March 2009) Long-term exposure to magnetic fields and the risks of Alzheimer's disease and breast cancer: Further biological research, Pathophysiology. 2009 Mar 9. [Epub ahead of print]. [View o [H+]

Davis RL, Mostofi FK, (August 1993) Cluster of testicular cancer in police officers exposed to hand-held radar, Am J Ind Med. 1993 Aug;24(2):231-3. [H+]

Davis S et al, (August 2006) Effects of 60-Hz magnetic field exposure on nocturnal 6-sulfatoxymelatonin, estrogens, luteinizing hormone, and follicle-stimulating hormone in healthy reproductive-age women: results of a crossover trial, Ann Epid [H+]

Davis S et al, (October 2001) Residential magnetic fields, light-at-night, and nocturnal urinary 6-sulfatoxymelatonin concentration in women, Am J Epidemiol. 2001 Oct 1;154(7):591-600. [H+]

D'Costa H et al, (December 2003) Human brain wave activity during exposure to radiofrequency field emissions from mobile phones, Australas Phys Eng Sci Med. 2003 Dec;26(4):162-7. [H+]

de Gannes FP et al, (November 2009) A confirmation study of Russian and Ukrainian data on effects of 2450 MHz microwave exposure on immunological processes and teratology in rats, Radiat Res. 2009 Nov;172(5):617-24. [V [W-]

de Gannes FP et al, (October 2009) Amyotrophic lateral sclerosis (ALS) and extremely-low frequency (ELF) magnetic fields: a study in the SOD-1 transgenic mouse model, Amyotroph Lateral Scler. 2009 Oct-Dec;10(5-6):370-3 [View Comments and Links [H-]

De Iuliis GN et al, (July 2009) Mobile phone radiation induces reactive oxygen species production and DNA damage in human spermatozoa in vitro, PLoS One. 2009 Jul 31;4(7):e6446. [H+]

de Pomerai DI et al, (May 2003) Microwave radiation can alter protein conformation without bulk heating, FEBS Lett. 2003 May 22;543(1-3):93-7. [H+]

De Roos AJ et al, (September 2001) Parental occupational exposures to electromagnetic fields and radiation and the incidence of neuroblastoma in offspring, Epidemiology. 2001 Sep;12(5):508-17. [H*]

de Salles AA et al, (2006) Electromagnetic absorption in the head of adults and children due to mobile phone operation close to the head, Electromagn Biol Med. 2006;25(4):349-60. [H*]

de Tommaso M et al, (October 2009) Mobile phones exposure induces changes of contingent negative variation in humans, Neurosci Lett. 2009 Oct 23;464(2):79-83. Epub 2009 Aug 21. [H+]

Dees C et al, (October 1996) Effects of 60-Hz fields, estradiol and xenoestrogens on human breast cancer cells, Radiat Res. 1996 Oct;146(4):444-52. [H-]

Degrave E et al, (2005) All-cause mortality among Belgian military radar operators: a 40-year controlled longitudinal study, Eur J Epidemiol. 2005;20(8):677-81. [H-]

Del Re B et al, (December 2009) Extremely low frequency magnetic field exposure affects DnaK and GroEL expression in E. coli cells with impaired heat shock response, Gen Physiol Biophys. 2009 Dec;28(4):420-4. [View on [W+]

Del Vecchio G et al, (May 2009) Continuous exposure to 900MHz GSM-modulated EMF alters morphological maturation of neural cells, Neurosci Lett. 2009 May 22;455(3):173-7. Epub 2009 Mar 24. [H+]

Del Vecchio G et al, (October 2009) Effect of radiofrequency electromagnetic field exposure on in vitro models of neurodegenerative disease, Bioelectromagnetics. 2009 Oct;30(7):564-72. [H+]

Deltour I et al, (December 2009) Time trends in brain tumor incidence rates in Denmark, Finland, Norway, and Sweden, 1974-2003, J Natl Cancer Inst. 2009 Dec 16;101(24):1721-4. [H*]

Desai NR et al, (October 2009) Pathophysiology of cell phone radiation: oxidative stress and carcinogenesis with focus on male reproductive system, Reprod Biol Endocrinol. 2009 Oct 22;7:114. [H+]

Desjobert H et al, (1995) Effects of 50 Hz magnetic fields on C-myc transcript levels in nonsynchronized and synchronized human cells, Bioelectromagnetics. 1995;16(5):277-83. [H-]

DeVault, T.L., Reinhart, B.D., Brisbin, I.L. & Rhodes, O.E. (2005) Flight Behavior of Black and Turkey Vultures: Implications for Reducing Bird-Aircraft Collisions. The Journal of Wildlife Management, 69, 601-608. [B*]

Di Campli E et al, (June 2010) Effects of extremely low-frequency electromagnetic fields on Helicobacter pylori biofilm, Curr Microbiol. 2010 Jun;60(6):412-8. Epub 2009 Dec 24. [H+]

Dibirdik I et al, (February 1998) Stimulation of Src family protein-tyrosine kinases as a proximal and mandatory step for SYK kinase-dependent phospholipase Cgamma2 activation in lymphoma B cells exposed to low energy electromagnetic fields, J [H+]

Diem E et al, (June 2005) Non-thermal DNA breakage by mobile-phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro, Mutat Res. 2005 Jun 6;583(2):178-83. [View on Pubme [H+]

Dimida A et al, (June 2010) Electric and magnetic fields do not modify the biochemical properties of frtl-5 cells, J Endocrinol Invest. 2010 Jun 11. [Epub ahead of print]. [H-]

Divan H et al, (December 2010) Cell phone use and behavioural problems in young children, J Epidemiol Community Health (2010). doi:10.1136/jech.2010.115402. [H+]

Divan H et al, (May 2008) Prenatal and Postnatal Exposure to Cell Phone Use, Epidemiology. 2008 May 7 [Epub ahead of print]. [H+]

Djeridane Y et al, (March 2008) Influence of Electromagnetic Fields Emitted by GSM-900 Cellular Telephones on the Circadian Patterns of Gonadal, Adrenal and Pituitary Hormones in Men, Radiat Res. 2008 Mar;169(3):337-43 [View Comments and Links [H-]

Dmoch A, Moszczynski P, (1998) Levels of immunoglobulin and subpopulations of T lymphocytes and NK cells in men occupationally exposed to microwave radiation in frequencies of 6-12 GHz, Med Pr. 1998;49(1):45-9. [View o [H+]

Dobson J, St. Pierre T, (October 1996) Application of the ferromagnetic transduction model to D.C. and pulsed magnetic fields: effects on epileptogenic tissue and implications for cellular phone safety, Biochem Biophys Res Commun 1996 Oct 23;2 [H+]

Dolk H et al, (January 1997) Cancer incidence near radio and television transmitters in Great Britain. I. Sutton Coldfield transmitter, Am J Epidemiol. 1997 Jan 1;145(1):1-9. [H+]

Dolk H et al, (January 1997) Cancer incidence near radio and television transmitters in Great Britain. II. All high power transmitters, Am J Epidemiol. 1997 Jan 1;145(1):10-7.. [H*]

Donnellan M et al, (July 1997) Effects of exposure to electromagnetic radiation at 835 MHz on growth, morphology and secretory characteristics of a mast cell analogue, RBL-2H3, Cell Biol Int. 1997 Jul;21(7):427-39. [Vi [H+]

Draper G et al, (June 2005) Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study, BMJ. 2005 Jun 4;330(7503):1290. [H+]

Duan L et al, (March 1998) Observations of changes in neurobehavioral functions in workers exposed to high-frequency radiation, Zhonghua Yu Fang Yi Xue Za Zhi. 1998 Mar;32(2):109-11. [H+]

Dundar B et al, (August 2009) The effect of the prenatal and post-natal long-term exposure to 50 Hz electric field on growth, pubertal development and IGF-1 levels in female Wistar rats, Toxicol Ind Health. 2009 Aug;25(7):479-87 [View Comments [W+]

Eberhardt JL et al, (2008) Blood-brain barrier permeability and nerve cell damage in rat brain 14 and 28 days after exposure to microwaves from GSM mobile phones, Electromagn Biol Med. 2008;27(3):215-29. [View on Pubme [W+]

Edelstyn N, Oldershaw A, (January 2002) The acute effects of exposure to the electromagnetic field emitted by mobile phones on human attention, Neuroreport. 2002 Jan 21;13(1):119-21. [H+]

Eger H et al, (November 2004) The Influence of Being Physically Near to a Cell Phone Transmission Mast on the Incidence of Cancer, Umwelt Medizin Gesellschaft 17,4 2004. [H+]

Einstein AJ et al, (July 2007) Estimating risk of cancer associated with radiation exposure from 64-slice computed tomography coronary angiography, JAMA. 2007 Jul 18;298(3):317-23. [H+]

Eleuteri AM et al, (2009) 50 Hz extremely low frequency electromagnetic fields enhance protein carbonyl groups content in cancer cells: effects on proteasomal systems, J Biomed Biotechnol. 2009;2009:834239. Epub 2009 Aug 5 [View Comments and L [H+]

Elliott P et al, (June 2010) Mobile phone base stations and early childhood cancers: case-control study, BMJ. 2010 Jun 22;340:c3077. doi: 10.1136/bmj.c3077. [H-]

Eltiti S et al, (February 2007) Development and evaluation of the electromagnetic hypersensitivity questionnaire, Bioelectromagnetics. 2007 Feb;28(2):137-51. [H*]

Eltiti S et al, (May 2009) Short-term exposure to mobile phone base station signals does not affect cognitive functioning or physiological measures in individuals who report sensitivity to electromagnetic fields and controls, Bioelectromagneti [H-]

Eltiti S et al, (November 2007) Does short-term exposure to mobile phone base station signals increase symptoms in individuals who report sensitivity to electromagnetic fields? A double-blind randomized provocation study., Environ Health Persp [H-]

Elwood JM, (February 2006) Childhood leukemia and residential magnetic fields: are pooled analyses more valid than the original studies?, Bioelectromagnetics. 2006 Feb;27(2):112-8. [H*]

EMR - A Bibliography of Scientific Papers. [H*]

Erdal N et al, (March 2008) Effects of Long-term Exposure of Extremely Low Frequency Magnetic Field on Oxidative/Nitrosative Stress in Rat Liver, J Radiat Res (Tokyo). 2008 Mar;49(2):181-7. [H+]

Eriksson N et al, (December 1997) The psychosocial work environment and skin symptoms among visual display terminal workers: a case referent study, Int J Epidemiol. 1997 Dec;26(6):1250-7. [H+]

Erogul O et al, (October 2006) Effects of electromagnetic radiation from a cellular phone on human sperm motility: an in vitro study, Arch Med Res 37(7):840-3. [H+]

Erren TC, (2001) A meta-analysis of epidemiologic studies of electric and magnetic fields and breast cancer in women and men, Bioelectromagnetics. 2001;Suppl 5:S105-19. [H*]

Esen F, Esen H, (March 2006) Effect of electromagnetic fields emitted by cellular phones on the latency of evoked electrodermal activity, Int J Neurosci. 2006 Mar;116(3):321-9. [H+]

Espinosa JM et al, (July 2006) Exposure to AC and DC magnetic fields induces changes in 5-HT1B receptor binding parameters in rat brain membranes, Bioelectromagnetics. 2006 Jul;27(5):414-22. [W+]

Eulitz C et al, (October 1998) Mobile phones modulate response patterns of human brain activity, Neuroreport. 1998 Oct 5;9(14):3229-32. [H+]

Everaert J, Bauwens D, (2007) A possible effect of electromagnetic radiation from mobile phone base stations on the number of breeding house sparrows (Passer domesticus), Electromagn Biol Med. 2007;26(1):63-72. [View o [B+]

Fabbro-Peray P et al, (April 2001) Environmental risk factors for non-Hodgkin's lymphoma: a population-based case-control study in Languedoc-Roussillon, France, Cancer Causes Control. 2001 Apr;12(3):201-12. [View on Pu [H*]

Fadel RA et al, (June 2006) Growth assessment of children exposed to low frequency electromagnetic fields at the Abu Sultan area in Ismailia (Egypt), Anthropol Anz. 2006 Jun;64(2):211-26. [H+]

Falone S et al, (June 2008) Chronic exposure to 50Hz magnetic fields causes a significant weakening of antioxidant defence systems in aged rat brain, Int J Biochem Cell Biol. 2008 Jun 10. [Epub ahead of print]. [View o [W+]

Falzone N et al, (March 2010) The effect of pulsed 900-MHz GSM mobile phone radiation on the acrosome reaction, head morphometry and zona binding of human spermatozoa, Int J Androl. 2010 Mar 7. [Epub ahead of print]. [[H+]

Fanelli, C., Coppola, S., Barone, R., Colussi, C., Gualandi, G., Volpe, P. & Ghibelli, L. (1999) Magnetic fields increase cell survival by inhibiting apoptosis via modulation of Ca2+ influx. The FASEB Journal, 13, 95. [H+]

Fang M, Malone D, (April 2010) Experimental verification of a radiofrequency power model for Wi-Fi technology, Health Phys. 2010 Apr;98(4):574-83. [H*]

Fazzo L et al, (April 2009) Morbidity experience in populations residentially exposed to 50 hz magnetic fields: methodology and preliminary findings of a cohort study, Int J Occup Environ Health. 2009 Apr-Jun;15(2):133-42 [View Comments and Li [H+]

Fedrowitz M et al, (January 2004) Significant differences in the effects of magnetic field exposure on 7,12-dimethylbenz(a)anthracene-induced mammary carcinogenesis in two substrains of Sprague-Dawley rats, Cancer Res. 2004 Jan 1;64(1):243-51 [W+]

Fedrowitz M et al, (March 2002) Magnetic field exposure increases cell proliferation but does not affect melatonin levels in the mammary gland of female Sprague Dawley rats, Cancer Res. 2002 Mar 1;62(5):1356-63. [View [W+]

Fedrowitz M, Loscher W, (January 2008) Exposure of Fischer 344 rats to a weak power frequency magnetic field facilitates mammary tumorigenesis in the DMBA model of breast cancer, Carcinogenesis. 2008 Jan;29(1):186-93. [W+]

Fejes I et al, (September 2005) Is there a relationship between cell phone use and semen quality?, Arch Androl. 2005 Sep-Oct;51(5):385-93. [H+]

Fernandez C et al, (July 2005) Comparison of Electromagnetic Absorption Characteristics in the Head of Adult and a Children for 1800 MHz Mobile Phones, Conference Proceeding from the 2005 SBMO/IEEE MTT-S International Conference on Microwave a [H*]

Fernie, K. & Reynolds, S. (2005) The effects of electromagnetic fields from power lines on avian reproductive biology and physiology: a review. Journal of Toxicology and Environmental Health-Part B-Critical Reviews, 8, 127. [B+]

Fernie, K.J. & Bird, D.M. (2001) Evidence of oxidative stress in American kestrels exposed to electromagnetic fields. Environmental research, 86, 198–207. [B+]

Ferreira A et al, (December 2006) Ultra high frequency-electromagnetic field irradiation during pregnancy leads to an increase in erythrocytes micronuclei incidence [H+]

Fews AP et al, (December 1999) Corona ions from powerlines and increased exposure to pollutant aerosols, Int J Radiat Biol. 1999 Dec;75(12):1523-31. [H+]

Fews AP et al, (December 1999) Increased exposure to pollutant aerosols under high voltage power lines, Int J Radiat Biol. 1999 Dec;75(12):1505-21. [H+]

Feychting M et al, (July 1998) Magnetic fields and breast cancer in Swedish adults residing near high-voltage power lines, Epidemiology. 1998 Jul;9(4):392-7. [H*]

Feychting M et al, (July 2003) Occupational magnetic field exposure and neurodegenerative disease, Epidemiology. 2003 Jul;14(4):413-9; discussion 427-8. [H+]

Feychting M, Ahlbom A, (October 1993) Magnetic fields and cancer in children residing near Swedish high-voltage power lines, Am J Epidemiol. 1993 Oct 1;138(7):467-81. [H+]

Feychting M, Ahlbom A, (September 1994) Magnetic fields, leukemia, and central nervous system tumors in Swedish adults residing near high-voltage power lines, Epidemiology. 1994 Sep;5(5):501-9. [H+]

Feychting M, Forssen U, (May 2006) Electromagnetic fields and female breast cancer, Cancer Causes Control. 2006 May;17(4):553-8. [H-]

Finnie JW et al, (April 2009) Heat shock protein induction in fetal mouse brain as a measure of stress after whole of gestation exposure to mobile telephony radiofrequency fields, Pathology. 2009 Apr;41(3):276-9. [View [H-]

Focke F et al, (January 2010) DNA fragmentation in human fibroblasts under extremely low frequency electromagnetic field exposure, Mutat Res. 2010 Jan 5;683(1-2):74-83. [H+]

Forman SA et al, (October 1995) Psychological symptoms and intermittent hypertension following acute microwave exposure, J Occup Med. 1982 Nov;24(11):932-4. [H+]

Forssen UM et al, (January 2000) Occupational and residential magnetic field exposure and breast cancer in females, Epidemiology. 2000 Jan;11(1):24-9. [H*]

Foster KR, (March 2007) Radiofrequency exposure from wireless LANs utilizing Wi-Fi technology, Health Phys. 2007 Mar;92(3):280-9. [H*]

Foster, K.R. & Repacholi, M.H. (1999) Environmental impacts of electromagnetic fields from major electrical technologies. Proceedings of an International Seminar on. Effects of Electromagnetic Fields on The living Environment, Germany p. 4–5. [H+]

Fragopoulou AF et al, (June 2010) Whole body exposure with GSM 900MHz affects spatial memory in mice, Pathophysiology. 2010 Jun;17(3):179-187. Epub 2009 Dec 1. [W+]

Franzellitti S et al, (October 2008) HSP70 Expression in Human Trophoblast Cells Exposed to Different 1.8 GHz Mobile Phone Signals, Rad. Res. 2008 Oct;170(4): 488-497. [H+]

Frei P et al, (August 2009) Temporal and spatial variability of personal exposure to radio frequency electromagnetic fields, Environ Res. 2009 Aug;109(6):779-85. Epub 2009 [H*]

French PW et al, (June 1997) Electromagnetic radiation at 835 MHz changes the morphology and inhibits proliferation of a human astrocytoma cell line, Bioelectrochemistry and Bioenergetics, June 1997;43(1):13-18. [H+]

Freude G et al, (1998) Effects of microwaves emitted by cellular phones on human slow brain potentials, Bioelectromagnetics. 1998;19(6):384-7. [H+]

Freude G et al, (January 2000) Microwaves emitted by cellular telephones affect human slow brain potentials, Eur J Appl Physiol. 2000 Jan;81(1-2):18-27. [H+]

Frey AH, (March 1998) Headaches from cellular telephones: are they real and what are the implications?, Environ Health Perspect. 1998 Mar;106(3):101-3. [H*]

Friedman J et al, (August 2007) Mechanism of a short-term ERK activation by electromagnetic fields at mobile phone frequency, Biochem J. 2007 Aug 1;405(3):559-68. [H+]

Fritzer G et al, (May 2007) Effects of short- and long-term pulsed radiofrequency electromagnetic fields on night sleep and cognitive functions in healthy subject, Bioelectromagnetics. 2007 May;28(4):316-25. [View on P [H-]

Fuma H. (1998) Effects of gamma-rays on the populations of the steady-state ecological microcosm. International journal of radiation biology, 74, 145–150. [H+]

Funch DP et al, (May 1996) Utility of telephone company records for epidemiologic studies of cellular telephones, Epidemiology. 1996 May;7(3):299-302. [H*]

Funk RH et al, (2009) Electromagnetic effects - From cell biology to medicine, Prog Histochem Cytochem. 2009;43(4):177-264. Epub 2008 Sep 18. [H*]

Furubayashi T et al, (September 2008) Effects of short-term W-CDMA mobile phone base station exposure on women with or without mobile phone related symptoms, Bioelectromagnetics. 2008 Sep 8. [Epub ahead of print]. [Vie [H-]

Gajendiran, N., Tanaka, K., Kumaravel, T.S. & Kamada, N. (2001) Neutron-induced adaptive response studied in Go human lymphocytes using the comet assay. Journal of radiation research, 42, 91-101. [H*]

Gajski G et al, (March 2009) Radioprotective effects of honeybee venom (Apis mellifera) against 915-MHz microwave radiation-induced DNA damage in wistar rat lymphocytes: in vitro study, Int J Toxicol. 2009 Mar-Apr;28(2):88-98 [View Comments an [W+]

Galloni, P., Parazzini, M., Piscitelli, M., Pinto, R., Lovisolo, G.A., Tognola, G., Marino, C. & Ravazzani, P. (2005) Electromagnetic fields from mobile phones do not affect the inner auditory system of Sprague-Dawley rats. Radiation research, 164, 798-804. [W-]

Galvanovskis J et al, (1999) Cytoplasmic Ca2+ oscillations in human leukemia T-cells are reduced by 50 Hz magnetic fields, Bioelectromagnetics. 1999;20(5):269-76. [H+]

Gandhi, G. & Singh, P. (2005) Cytogenetic damage in mobile phone users: Preliminary data. International Journal of Human Genetics, 5, 259. [H+]

Gandhi, G. (2005a) Mobile Phone Users: Another High Health Risk Group. Journal of Human Ecology, 18, 85-92. [H+]

Gandhi, G. (2005b) Genetic damage in mobile phone users: some preliminary findings. Indian Journal of Human Genetics, 11, 99. [H+]

Gangi S, Johansson O, (April 2000) A theoretical model based upon mast cells and histamine to explain the recently proclaimed sensitivity to electric and/or magnetic fields in humans, Med Hypotheses. 2000 Apr;54(4):663-71 [View Comments and Li [H+]

Gangi S, Johansson O, (December 1997) Skin changes in "screen dermatitis" versus classical UV- and ionizing irradiation-related damage--similarities and differences, Exp Dermatol. 1997 Dec;6(6):283-91. [H+]

Garaj-Vrhovac V, Orescanin V, (January 2008) Assessment of DNA sensitivity in peripheral blood leukocytes after occupational exposure to microwave radiation: the alkaline comet assay and chromatid breakage assay, Cell Biol Toxicol. 2008 Jan 23 [H*]

Garcia AM et al, (April 2008) Occupational exposure to extremely low frequency electric and magnetic fields and Alzheimer disease: a meta-analysis, Int J Epidemiol. 2008 Feb 2 [Epub ahead of print]. [H+]

Garcia Callejo FJ et al, (May 2005) Hearing level and intensive use of mobile phones, Acta Otorrinolaringol Esp. 2005 May;56(5):187-91. [H+]

Garip AI, Akan Z, (June 2010) Effect of ELF-EMF on number of apoptotic cells; correlation with reactive oxygen species and HSP, Acta Biol Hung. 2010 Jun;61(2):158-67. [H+]

George DF et al, (May 2008) Non-thermal effects in the microwave induced unfolding of proteins observed by chaperone binding, Bioelectromagnetics. 2008 May;29(4):324-30. [H+]

Ghandi O, Kang G, (1996) Effect of the head size on SAR for mobile telephones at 835 and 1900MHz, Bioelectromagnetics Society 23rd Annual Meeting. St. Paul, Minnesota, USA, June 10-14, 2001, p. 52. [H*]

Ghandi O, Kang G, (May 2002) Some present problems and a proposed experimental phantom for SAR compliance testing of cellular telephones at 835 and 1900 MHz, Phys. Med. Biol. 47 1501 18. [H*]

Ghosh, A., Suraiya, J., Warren, E., Howe, E.W. & Brecht, B. (2008) Fascist Trends and Health: The Case of Mobile Phones in Indian Society. Bio-social issues in health, 228. [H+]

Girgert R et al, (April 2009) Exposure of mcf-7 breast cancer cells to electromagnetic fields up-regulates the plasminogen activator system, Int J Gynecol Cancer. 2009 Apr;19(3):334-8. [H+]

Girgert R et al, (April 2010) Signal transduction of the melatonin receptor MT1 is disrupted in breast cancer cells by electromagnetic fields, Bioelectromagnetics. 2010 Apr;31(3):237-45. [H+]

Girgert R et al, (November 2005) Induction of tamoxifen resistance in breast cancer cells by ELF electromagnetic fields, Biochem Biophys Res Commun. 2005 Nov 4;336(4):1144-9. [H+]

Gobba F et al, (October 2009) Natural killer cell activity decreases in workers occupationally exposed to extremely low frequency magnetic fields exceeding 1 microT, Int J Immunopathol Pharmacol. 2009 Oct-Dec;22(4):1059-66 [View Comments and L [H+]

Gobba F et al, (September 2008) Extremely Low Frequency-Magnetic Fields (ELF-EMF) occupational exposure and natural killer activity in peripheral blood lymphocytes, Sci Total Environ. 2008 Sep 18. [Epub ahead of print] [View Comments and Links [H+]

Goel, H.C., Prasad, D.J., SINGH, S., Sagar, R.K., Agrawala, P.K., Bala, M., Sinha, A.K. & Dogra, R. (2004) Radioprotective potential of an herbal extract of Tinospora cordifolia. Journal of radiation research, 45, 61-68. [P*]

Gold S et al, (1994) Exposure of simian virus-40-transformed human cells to magnetic fields results in increased levels of T-antigen mRNA and protein, Bioelectromagnetics. 1994;15(4):329-36. [H+]

Goldoni J et al, (September 1993) Health status of personnel occupationally exposed to radiowaves, Arh Hig Rada Toksikol. 1993 Sep;44(3):223-8. [H+]

Goldsmith JR, (January 1995) Epidemiologic Evidence of Radiofrequency Radiation (Microwave) Effects on Health in Military, Broadcasting, and Occupational Studies, Int J Occup Environ Health. 1995 Jan;1(1):47-57. [View [H+]

Goldwein O, Aframian DJ, (September 2009) The influence of handheld mobile phones on human parotid gland secretion, Oral Dis. 2009 Sep 8. [Epub ahead of print] [View Comments [H+]

Gonet B et al, (July 2009) Effects of extremely low-frequency magnetic fields on the oviposition of Drosophila melanogaster over three generations, Bioelectromagnetics. 2009 Jul 23. [Epub ahead of print]. [View on Pubm [W+]

Goodman EM et al, (1994) Magnetic fields after translation in Escherichia coli, Bioelectromagnetics. 1994;15(1):77-83. [W+]

Goodman R et al, (July 2009) Extremely low frequency electromagnetic fields activate the ERK cascade, increase hsp70 protein levels and promote regeneration in Planaria, Int J Radiat Biol. 2009 Jul 9:1-9. [Epub ahead of print] [View Comments a [W+]

Goraca A et al, (June 2010) Effects of extremely low frequency magnetic field on the parameters of oxidative stress in heart, J Physiol Pharmacol. 2010 Jun;61(3):333-8. [H+]

Goudarzi I et al, (May 2010) Pulsed electromagnetic fields accelerate wound healing in the skin of diabetic rats, Bioelectromagnetics. 2010 May;31(4):318-23. [W*]

Gould, J.L. (1980) The case for magnetic sensitivity in birds and bees (such as it is). American Scientist, 68, 256–267. [B*]

Gould, J.L. (1984) Magnetic Field Sensitivity in Animals. Annual Review of Physiology, 46, 585-598. [W*]

Gould, J.L. (2008) Animal Navigation: The Evolution of Magnetic Orientation. Current Biology, 18, R482-R484. [W*]

Graham C, Cook MR, (1999) Human sleep in 60 Hz magnetic fields, Bioelectromagnetics. 1999;20(5):277-83. [H+]

Grajewski B et al, (October 2000) Semen quality and hormone levels among radiofrequency heater operators, J Occup Environ Med. 2000 Oct;42(10):993-1005. [H+]

Gray, R.H. (1997) A Description of Long-Term Environmental Monitoring and Assessment Programs at Two U.S. Department of Energy Sites. Water Environment Research, 69, 1015-1021. [H*]

Grayson JK, (March 1996) Radiation exposure, socioeconomic status, and brain tumor risk in the US Air Force: a nested case-control study, Am J Epidemiol. 1996 Mar 1;143(5):480-6. [H+]

Green LM et al, (July 1999) A case-control study of childhood leukemia in southern Ontario, Canada, and exposure to magnetic fields in residences, Int J Cancer. 1999 Jul 19;82(2):161-70. [H+]

Greene JJ et al, (May 1993) Gene-specific modulation of RNA synthesis and degradation by extremely low frequency electromagnetic fields, Cell Mol Biol (Noisy-le-grand). 1993 May;39(3):261-8. [H+]

Greenland S et al, (November 2000) A pooled analysis of magnetic fields, wire codes, and childhood leukemia. Childhood Leukemia-EMF Study Group, Epidemiology. 2000 Nov;11(6):624-34. [H*]

Grigor'ev IuG, (September 2003) Biological effects of mobile phone electromagnetic field on chick embryo (risk assessment using the mortality rate), Radiats Biol Radioecol. 2003 Sep-Oct;43(5):541-3. [B+]

Guberan E et al, (October 1994) Gender ratio of offspring and exposure to shortwave radiation among female physiotherapists, Scand J Work Environ Health. 1994 Oct;20(5):345-8. [H-]

Gul A et al, (February 2009) The effects of microwave emitted by cellular phones on ovarian follicles in rats, Arch Gynecol Obstet. 2009 Feb 25. [Epub ahead of print]. [W+]

Gul A et al, (February 2009) The effects of microwave emitted by cellular phones on ovarian follicles in rats, Arch Gynecol Obstet. 2009 Feb 25. [Epub ahead of print]. [W+]

Guler G et al, (March 2010) The effect of radiofrequency radiation on DNA and lipid damage in non-pregnant and pregnant rabbits and their newborns, Gen Physiol Biophys. 2010 Mar;29(1):59-66. [W+]

Guney M et al, (August 2007) 900 MHz radiofrequency-induced histopathologic changes and oxidative stress in rat endometrium: protection by vitamins E and C, Toxicol Ind Health. 2007 Aug;23(7):411-20. [W+]

Ha M et al, (August 2007) Radio-frequency radiation exposure from AM radio transmitters and childhood leukemia and brain cancer, Am J Epidemiol. 2007 Aug 1;166(3):270-9. [H+]

Ha M et al, (December 2003) Incidence of cancer in the vicinity of Korean AM radio transmitters, Arch Environ Health. 2003 Dec;58(12):756-62. [H+]

Haarala C et al, (May 2007) Pulsed and continuous wave mobile phone exposure over left versus right hemisphere: Effects on human cognitive function, Bioelectromagnetics 2007 May;28(4):289-95. [H-]

Habash RW et al, (2003) Health risks of electromagnetic fields. Part I: Evaluation and assessment of electric and magnetic fields, Crit Rev Biomed Eng. 2003;31(3):141-95. [H*]

Habash RW et al, (April 2009) Recent advances in research on radiofrequency fields and health: 2004-2007, J Toxicol Environ Health B Crit Rev. 2009 Apr;12(4):250-88. [H*]

Hakansson N et al, (July 2003) Neurodegenerative diseases in welders and other workers exposed to high levels of magnetic fields, Epidemiology. 2003 Jul;14(4):420-6; discussion 427-8. [H+]

Hakansson N et al, (September 2003) Occupational exposure to extremely low frequency magnetic fields and mortality from cardiovascular disease, Am J Epidemiol. 2003 Sep 15;158(6):534-42. [H*]

Hallberg O, Johansson O, (2005) FM broadcasting exposure time and malignant melanoma incidence, Electromagnetic Biology and Medicine 24; 1-8. [H+]

Hallberg O, Johansson O, (2005) FM broadcasting exposure time and malignant melanoma incidence, Electromagnetic Biology and Medicine 24; 1-8. [H+]

Hallberg O, Johansson O, (January 2002) Melanoma incidence and frequency modulation (FM) broadcasting, Arch Environ Health. 2002 Jan-Feb;57(1):32-40. [H+]

Hallberg O, Johansson O, (July 2004) Malignant melanoma of the skin - not a sunshine story!, Med Sci Monit. 2004 Jul;10(7):CR336-40. [H+]

Hallberg O, Johansson O, (March 2009) Apparent decreases in Swedish public health indicators after 1997-Are they due to improved diagnostics or to environmental factors?, Pathophysiology. 2009 Jun;16(1):43-6. Epub 2009 Feb 10 [View Comments an [H*]

Hallberg, Ö. & Johansson, O. (2002) Melanoma incidence and frequency modulation (FM) broadcasting. Archives of Environmental Health: An International Journal, 57, 32–40. [H+]

Hallberg, Ö. (2007) Radio, TV towers linked to increased risk of melanoma. [H+]

Han YY et al, (March 2009) Cell phone use and acoustic neuroma: the need for standardized questionnaires and access to industry data, 2009 Mar 26. [Epub ahead of print]. [H*]

Hanowski, J.A.M., Niemi, G.G. & Blake, J.G. (1996) Response of breeding and migrating birds to extremely low frequency electromagnetic fields. Ecological Applications, 6, 910–919. [B-]

Hansen J, (January 2001) Increased breast cancer risk among women who work predominantly at night, Epidemiology. 2001 Jan;12(1):74-7. [H+]

Hansteen IL et al, (November 2009) Cytogenetic effects of exposure to 2.3 GHz radiofrequency radiation on human lymphocytes in vitro, Anticancer Res. 2009 Nov;29(11):4323-30. [H-]

Hardell L et al, (2005) Case-control study on cellular and cordless telephones and the risk for acoustic neuroma or meningioma in patients diagnosed 2000-2003, Neuroepidemiology. 2005;25(3):120-8. [H+]

Hardell L et al, (April 2007) Use of cellular and cordless telephones and risk of testicular cancer, Int J Androl. 2007 Apr;30(2):115-22. [H-]

Hardell L et al, (August 2002) Cellular and cordless telephones and the risk for brain tumours, Eur J Cancer Prev. 2002 Aug;11(4):377-86. [H+]

Hardell L et al, (August 2004) No association between the use of cellular or cordless telephones and salivary gland tumours, Occup Environ Med. 2004 Aug;61(8):675-9. [H-]

Hardell L et al, (December 1998) Case-control study on risk factors for testicular cancer, Int J Oncol. 1998 Dec;13(6):1299-303. [H+]

Hardell L et al, (December 2001) Ionizing radiation, cellular telephones and the risk for brain tumours, Eur J Cancer Prev. 2001 Dec;10(6):523-9. [H+]

Hardell L et al, (February 2003) Further aspects on cellular and cordless telephones and brain tumours, Int J Oncol. 2003 Feb;22(2):399-407. [H+]

Hardell L et al, (February 2006) Case-control study of the association between the use of cellular and cordless telephones and malignant brain tumors diagnosed during 2000-2003, Environ Res. 2006 Feb;100(2):232-41. [Vi [H+]

Hardell L et al, (July 1999) Use of cellular telephones and the risk for brain tumours: A case-control study, Int J Oncol. 1999 Jul;15(1):113-6. [H+]

Hardell L et al, (June 2005) Use of cellular telephones and brain tumour risk in urban and rural areas, Occup Environ Med. 2005 Jun;62(6):390-4. [H+]

Hardell L et al, (March 2003) Vestibular schwannoma, tinnitus and cellular telephones, Neuroepidemiology 2003 Mar-Apr;22(2):124-9. [H+]

Hardell L et al, (March 2009) Epidemiological evidence for an association between use of wireless phones and tumor diseases, Pathophysiology. 2009 Mar 4. [Epub ahead of print]. [H+]

Hardell L et al, (May 2000) Case-control study on radiology work, medical x-ray investigations, and use of cellular telephones as risk factors for brain tumors, MedGenMed. 2000 May 4;2(2):E2. [H+]

Hardell L et al, (May 2008) Meta-analysis of long-term mobile phone use and the association with brain tumours, Int J Oncol. 2008 May;32(5):1097-103. [H+]

Hardell L et al, (October 2006) Tumour risk associated with use of cellular telephones or cordless desktop telephones, World J Surg Oncol 2006 Oct 11;4:74. [H+]

Hardell L et al, (September 2005) Use of cellular or cordless telephones and the risk for non-Hodgkin's lymphoma, Int Arch Occup Environ Health. 2005 Sep;78(8):625-32. [H+]

Hardell L et al, (September 2006) Pooled analysis of two case-control studies on use of cellular and cordless telephones and the risk for malignant brain tumours diagnosed in 1997-2003, Int Arch Occup Environ Health. 2006 Sep;79(8):630-9. Epub [H+]

Hardell L et al, (September 2007) Long-term use of cellular phones and brain tumours - increased risk associated with use for > 10 years, Occup Environ Med. 2007 Sep;64(9):626-32. [H+]

Hardell L, Carlberg M, (July 2009) Mobile phones, cordless phones and the risk for brain tumours, Int J Oncol. 2009 Jul;35(1):5-17.. [H+]

Hardell L, Sage C, (February 2008) Biological effects from electromagnetic field exposure and public exposure standards, Biomed Pharmacother. 2008 Feb;62(2):104-9. [H*]

Hardell, L., Carlberg, M., Soderqvist, F. & Hansson Mild, K. (2008) Meta-analysis of long-term mobile phone use and the association with brain tumours. International journal of oncology, 32, 1097–1104. [H+]

Hardell, L., Carlberg, M., Söderqvist, F., Mild, K.H. & Morgan, L.L. (2007) Long-term use of cellular phones and brain tumours: increased risk associated with use for? 10 years. Occupational and Environmental Medicine, 64, 626. [H+]

Harris SR et al, (February 2009) Effect of magnetic fields on cryptochrome-dependent responses in Arabidopsis thaliana, 2009 Feb 25. [Epub ahead of print]. [P+]

Harst, W., Kuhn, J. & Stever, H. (2006) Can Electromagnetic Exposure Cause a Change in Behaviour? Studying Possible Non-Thermal Influences on Honey Bees–An Approach within the Framework of Educational Informatics. Acta Systemica-IIAS International Journal, 6, 1–6. [Es+]

Hartikka H et al, (April 2009) Mobile phone use and location of glioma: a case-case analysis, Bioelectromagnetics. 2009 Apr;30(3):176-82. [H*]

Hatch EE et al, (March 2000) Do confounding or selection factors of residential wiring codes and magnetic fields distort findings of electromagnetic fields studies?, Epidemiology. 2000 Mar;11(2):189-98. [View on Pubmed [H*]

Haugsdal B et al, (1998) Comparison of symptoms experienced by users of analogue and digital mobile phones: a Swedish-Norwegian epidemiological study, Arbetslivsrapport 23: 1998. [H+]

Havas M, (2006) Electromagnetic hypersensitivity: biological effects of dirty electricity with emphasis on diabetes and multiple sclerosis, Electromagn Biol Med. 2006;25(4):259-68. [H*]

Heath CW Jr, (January 1996) Electromagnetic field exposure and cancer: a review of epidemiologic evidence, CA Cancer J Clin. 1996 Jan-Feb;46(1):29-44. [H*]

Henry, L. & Narendra, P.S. (2004) Magnetic-Field-Induced DNA Strand Breaks in Brain Cells of the Rat. Environmental Health Perspectives, 112. [W+]

Henshaw DL et al, (April 2008) Can disturbances in the atmospheric electric field created by powerline corona ions disrupt melatonin production in the pineal gland?, J Pineal Res. 2008 Apr 1. [Epub ahead of print]. [Vi [H+]

Henshaw DL, (July 2002) Does our electricity distribution system pose a serious risk to public health?, Med Hypotheses. 2002 Jul;59(1):39-51. [H+]

Henshaw DL, Reiter RJ, (2005) Do magnetic fields cause increased risk of childhood leukemia via melatonin disruption?, Bioelectromagnetics. 2005;Suppl 7:S86-97. [H+]

Hepworth SJ et al, (April 2006) Mobile phone use and risk of glioma in adults: case-control study, BMJ. 2006 Apr 15;332(7546):883-7. [H*]

Hillert L et al, (February 2002) Prevalence of self-reported hypersensitivity to electric or magnetic fields in a population-based questionnaire survey, Scand J Work Environ Health. 2002 Feb;28(1):33-41. [View on Pubme [H*]

Hillert L et al, (March 2001) Environmental illness: fatigue and cholinesterase activity in patients reporting hypersensitivity to electricity, Environ Res. 2001 Mar;85(3):200-6. [H-]

Hillert L et al, (November 1999) Hypersensitivity to electricity: working definition and additional characterization of the syndrome, J Psychosom Res. 1999 Nov;47(5):429-38. [H*]

Hinton, T.G., Bedford, J.S., Congdon, J.C. & Whicker, F.W. (2004) Effects of Radiation on the Environment: A Need to Question Old Paradigms and Enhance Collaboration among Radiation Biologists and Radiation Ecologists. Radiation research, 162, 332-338. [H*]

Hirata A et al, (2010) Intercomparison of induced fields in Japanese male model for ELF magnetic field exposures: effect of different computational methods and codes, Radiat Prot Dosimetry. 2010;138(3):237-44. Epub 2009 Nov 22 [View Comments a [H*]

Hirose H et al, (July 2009) 1950 MHz IMT-2000 field does not activate microglial cells in vitro, Bioelectromagnetics. 2009 Jul 31. [Epub ahead of print]. [H-]

Hjollund NH et al, (November 1997) Semen analysis of personnel operating military radar equipment, Reprod Toxicol. 1997 Nov-Dec;11(6):897. [H+]

Ho, M.W. (2007) Mobile phones and vanishing bees. Science in Society, 34, 34. [H+]

Hocking B et al, (1988) Health aspects of radio-frequency radiation accidents. Part I: Assessment of health after a radio-frequency radiation accident, J Microw Power Electromagn Energy. 1988;23(2):67-74. [View on Pubm [H*]

Hocking B et al, (December 1996) Cancer incidence and mortality and proximity to TV towers, Med J Aust. 1996 Dec 2-16;165(11-12):601-5. [H+]

Hocking B, Gordon I, (September 2003) Decreased survival for childhood leukemia in proximity to television towers, Arch Environ Health. 2003 Sep;58(9):560-4. [H+]

Hocking B, Westerman R, (March 2003) Neurological effects of radiofrequency radiation, Occup Med 2003 Mar;53(2):123-7. [H+]

Hocking B, Westerman R, (October 2002) Neurological changes induced by a mobile phone, Occup Med (Lond). 2002 Oct;52(7):413-5. [H+]

Hocking B, Westerman R, (October 2002) Neurological changes induced by a mobile phone, Occup Med (Lond). 2002 Oct;52(7):413-5. [H+]

Hocking B, Westerman R, (September 2001) Neurological abnormalities associated with CDMA exposure, Occup Med (Lond). 2001 Sep;51(6):410-3. [View on [H*]

Hole, D.G., Whittingham, M.J., Bradbury, R.B., Anderson, G.Q.A., Lee, P.L.M., Wilson, J.D. & Krebs, J.R. (2002) Agriculture: Widespread local house-sparrow extinctions. Nature, 418, 931–932. [H+]

Holly EA et al, (January 1996) Intraocular melanoma linked to occupations and chemical exposures, Epidemiology. 1996 Jan;7(1):55-61. [H*]

Holt JA, (June 1980) Changing epidemiology of malignant melanoma in Queensland, Med J Aust. 1980 Jun 14;1(12):619-20. [H+]

Hondou T et al, (2006) Passive Exposure to Mobile Phones: Enhancement of Intensity by Reflection, J. Phys. Soc. Jpn. 75 (2006) 084801. [H*]

Hoskote, S.S., Kapdi, M. & Joshi, S.R. (2008) An Epidemiological Review of Mobile Telephones and Cancer. JAPI, 56, 980–984. [H-]

Hours M et al, (October 2007) Cell Phones and Risk of brain and acoustic nerve tumours: the French INTERPHONE case-control study, Rev Epidemiol Sante Publique. 2007 Oct;55(5):321-32. [H*]

Hoyto A et al, (June 2007) Ornithine decarboxylase activity is affected in primary astrocytes but not in secondary cell lines exposed to 872 MHz RF radiation, Int J Radiat Biol. 2007 Jun;83(6):367-74. [H+]

Hoyto A et al, (September 2008) Radiofrequency radiation does not significantly affect ornithine decarboxylase activity, proliferation, or caspase-3 activity of fibroblasts in different physiological conditions, Int J Radiat Biol. 2008 Sep;84([H-]

Hu J et al, (November 2009) Level of microwave radiation from mobile phone base stations built in residential districts, Wei Sheng Yan Jiu. 2009 Nov;38(6):712-6. [H*]

Huang TQ et al, (September 2008) Molecular responses of Jurkat T-cells to 1763 MHz radiofrequency radiation, Int J Radiat Biol. 2008 Sep;84(9):734-41. [H-]

Huber R et al, (December 2002) Electromagnetic fields, such as those from mobile phones, alter regional cerebral blood flow and sleep and waking EEG, J Sleep Res 2002 Dec;11(4):289-95. [H+]

Huber R et al, (February 2005) Exposure to pulse-modulated radio frequency electromagnetic fields affects regional cerebral blood flow, Eur J Neurosci. 2005 Feb;21(4):1000-6. [H+]

Huber R et al, (May 2003) Radio frequency electromagnetic field exposure in humans: Estimation of SAR distribution in the brain, effects on sleep and heart rate, Bioelectromagnetics. 2003 May;24(4):262-76. [View on Pub [H+]

Huber R et al, (October 2000) Exposure to pulsed high-frequency electromagnetic field during waking affects human sleep EEG, Neuroreport. 2000 Oct 20;11(15):3321-5. [H+]

Hug K et al, (January 2010) Parental occupational exposure to extremely low frequency magnetic fields and childhood cancer: a German case-control study, Am J Epidemiol. 2010 Jan 1;171(1):27-35. Epub 2009 Nov 25. [View [H-]

Hung CS et al, (June 2007) Mobile phone 'talk-mode' signal delays EEG-determined sleep onset, Neurosci Lett. 2007 Jun 21;421(1):82-6. [H+]

Huss A et al, (January 2007) Source of funding and results of studies of health effects of mobile phone use: systematic review of experimental studies, Environ Health Perspect. 2007 Jan;115(1):1-4. [H*]

Huss A et al, (November 2008) Residence Near Power Lines and Mortality From Neurodegenerative Diseases: Longitudinal Study of the Swiss Population, Am J Epidemiol. 2008 Nov 5. [Epub ahead of print]Click here to read. [[H+]

Huss A, Roosli M, (October 2006) Consultations in primary care for symptoms attributed to electromagnetic fields--a survey among general practitioners, BMC Public Health. 2006 Oct 30;6:267. [H*]

Hutter HP et al, (2004) Public perception of risk concerning celltowers and mobile phones, Soz Praventivmed. 2004;49(1):62-6. [H*]

Hutter HP et al, (May 2006) Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations, Occup Environ Med. 2006 May;63(5):307-13. [H+]

Hutter HP et al, (May 2006) Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations, Occup Environ Med. 2006 May;63(5):307-13. [H+]

Hutter, H.P., Moshammer, H., Wallner, P. & Kundi, M. (2006) Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations. Occupational and Environmental medicine, 63, 307. [H+]

Huttunen P et al, (March 2009) FM-radio and TV tower signals can cause spontaneous hand movements near moving RF reflector, Pathophysiology. 2009 Mar 4. [Epub ahead of print]. [H+]

Hyland, G., Chambers, G. & Programme, S. (2001) The Physiological and Environmental Effects on Non-ionising Electromagnetic Radiation. European Parliament, Directorate General for Research. [H+]

Ilonen K et al, (April 2008) Indoor transformer stations as predictors of residential ELF magnetic field exposure, Bioelectromagnetics. 2008 Apr;29(3):213-8. [H*]

Imge, E.B., KiliasoGlu, B., Devrim, E., Aetin, R. & Durak, I. (2010) Effects of mobile phone use on brain tissue from the rat and a possible protective role of vitamin C-a preliminary study. International Journal of Radiation Biology, 1-6. [W+]

Infante-Rivard C, Deadman JE, (July 2003) Maternal occupational exposure to extremely low frequency magnetic fields during pregnancy and childhood leukemia, Epidemiology. 2003 Jul;14(4):437-41. [H+]

Inskip PD et al, (January 2001) Cellular-telephone use and brain tumors, N Engl J Med. 2001 Jan 11;344(2):79-86. [H-]

Inskip PD et al, (Novermber 2010) Brain cancer incidence trends in relation to cellular telephone use in the United States, Neuro Oncol. 2010 Nov;12(11):1147-51. Epub 2010 Jul 16. [H-]

Inyang I et al, (December 2009) A new method to determine laterality of mobile telephone use in adolescents, Occup Environ Med. 2009 Dec 2. [Epub ahead of print]. [H*]

Iorio R et al, (August 2010) Involvement of mitochondrial activity in mediating ELF-EMF stimulatory effect on human sperm motility, Bioelectromagnetics. 2010 Aug 5. [Epub ahead of print]. [H+]

Irgens A et al, (December 1999) The effect of male occupational exposure in infertile couples in Norway, J Occup Environ Med. 1999 Dec;41(12):1116-20. [H*]

Irvine N et al, (November 2005) Definition, Epidemiology and Management of Electrical Sensitivity, HPA-RPD-010. [H*]

Ishido M et al, (February 2002) The mechanism of biological magnetic field effects on oncostatic actions of melatonin, RIKEN review - No. 44 (February, 2002). [H+]

Ishido M et al, (July 2001) Magnetic fields (MF) of 50 Hz at 1.2 microT as well as 100 microT cause uncoupling of inhibitory pathways of adenylyl cyclase mediated by melatonin 1a receptor in MF-sensitive MCF-7 cells, Carcinogenesis. 2001 Jul;2 [H+]

Ishido M et al, (July 2001) Magnetic fields (MF) of 50 Hz at 1.2 microT as well as 100 microT cause uncoupling of inhibitory pathways of adenylyl cyclase mediated by melatonin 1a receptor in MF-sensitive MCF-7 cells, Carcinogenesis. 2001 Jul;2 [H+]

Ivancsits S et al, (August 2002) Induction of DNA strand breaks by intermittent exposure to extremely-low-frequency electromagnetic fields in human diploid fibroblasts, Mutat Res. 2002 Aug 26;519(1-2):1-13. [View on Pu [H+]

Ivancsits S et al, (July 2003) Age-related effects on induction of DNA strand breaks by intermittent exposure to electromagnetic fields, Mech Ageing Dev. 2003 Jul;124(7):847-50. [H+]

Ivancsits S et al, (July 2003) Intermittent extremely low frequency electromagnetic fields cause DNA damage in a dose-dependent way, Int Arch Occup Environ Health. 2003 Jul;76(6):431-6. [H+]

Ivancsits S et al, (June 2005) Cell type-specific genotoxic effects of intermittent extremely low-frequency electromagnetic fields, Mutat Res. 2005 Jun 6;583(2):184-8. [H+]

Jahandideh S et al, (February 2010) Comparing performances of logistic regression and neural networks for predicting melatonin excretion patterns in the rat exposed to ELF magnetic fields, Bioelectromagnetics. 2010 Feb;31(2):164-71 [View Comme [W*]

Jahreis GP et al, (December 1998) Absence of 60-Hz, 0.1-mT magnetic field-induced changes in oncogene transcription rates or levels in CEM-CM3 cells, Biochim Biophys Acta. 1998 Dec 22;1443(3):334-42. [H-]

Janssen, T., Boege, P., Mikusch-Buchberg, J. & Raczek, J. (2005) Investigation of potential effects of cellular phones on human auditory function by means of distortion product otoacoustic emissions. The Journal of the Acoustical Society of America, 117, 1241. [H+]

Jauchem JR, (1997) Exposure to extremely-low-frequency electromagnetic fields and radiofrequency radiation: cardiovascular effects in humans, Int Arch Occup Environ Health. 1997;70(1):9-21. [H*]

Johansen C et al, (February 2001) Cellular telephones and cancer--a nationwide cohort study in Denmark, J Natl Cancer Inst. 2001 Feb 7;93(3):203-7. [H-]

Johansen C et al, (February 2002) Mobile phones and malignant melanoma of the eye, Br J Cancer. 2002 Feb 1;86(3):348-9. [H-]

Johansen C, (2004) Electromagnetic fields and health effects--epidemiologic studies of cancer, diseases of the central nervous system and arrhythmia-related heart disease, Scand J Work Environ Health. 2004;30 Suppl 1:1-30 [View Comments and Li [H-]

Johansen C, (September 2000) Exposure to electromagnetic fields and risk of central nervous system disease in utility workers, Epidemiology. 2000 Sep;11(5):539-43. [H+]

Johansen C, Olsen JH, (August 1998) Mortality from amyotrophic lateral sclerosis, other chronic disorders, and electric shocks among utility workers, Am J Epidemiol. 1998 Aug 15;148(4):362-8. [H+]

Johansson A et al, (January 2010) Symptoms, personality traits, and stress in people with mobile phone-related symptoms and electromagnetic hypersensitivity, J Psychosom Res. 2010 Jan;68(1):37-45. [H*]

Johansson O et al, (November 2001) Cutaneous mast cells are altered in normal healthy volunteers sitting in front of ordinary TVs/PCs--results from open-field provocation experiments, J Cutan Pathol. 2001 Nov;28(10):513-9. [View Comments and L [H+]

Johansson O et al, (October 1994) Skin changes in patients claiming to suffer from "screen dermatitis": a two-case open-field provocation study, Exp Dermatol. 1994 Oct;3(5):234-8. [H+]

Johansson O, (2006) Electrohypersensitivity: state-of-the-art of a functional impairment, Electromagn Biol Med. 2006;25(4):245-58. [H+]

Johnson Liakouris, A.G. (1998) Radiofrequency (RF) Sickness in the Lilienfeld Study: an effect of modulated microwaves? Archives of Environmental Health: An International Journal, 53, 236–238. [H+]

Joris, E. & Dirk, B. (2007) A possible effect of electromagnetic radiation from mobile phone base stations on the number of breeding house sparrows (Passer domesticus). Electromagnetic Biology and Medicine, 26, 63–72. [B+]

Joseph W et al, (May 2010) Estimation of whole-body SAR from electromagnetic fields using personal exposure meters, Bioelectromagnetics. 2010 May;31(4):286-95. [H*]

Joseph W et al, (October 2010) Assessment of general public exposure to LTE and RF sources present in an urban environment, Bioelectromagnetics. 2010 Oct;31(7):576-9. [H*]

Joubert V et al, (January 2008) Apoptosis is Induced by Radiofrequency Fields through the Caspase-Independent Mitochondrial Pathway in Cortical Neurons, Radiat Res. 2008 Jan;169(1):38-45. [H+]

Jurewicz, J., Hanke, W., Radwan, M. & Bonde, J. (2009) Environmental factors and semen quality. International Journal of Occupational Medicine and Environmental Health, 22, 305-329. [H+]

Juutilainen J et al, (January 2006) Do extremely low frequency magnetic fields enhance the effects of environmental carcinogens? A meta-analysis of experimental studies, Int J Radiat Biol. 2006 Jan;82(1):1-12. [View on [H+]

Juutilainen J, (2008) Do electromagnetic fields enhance the effects of environmental carcinogens?, Radiat Prot Dosimetry. 2008;132(2):228-31. [H+]

Juutilainen J, Kumlin T, (July 2006) Occupational magnetic field exposure and melatonin: interaction with light-at-night, Bioelectromagnetics. 2006 Jul;27(5):423-6. [H+]

Kabuto M et al, (August 2006) Childhood leukemia and magnetic fields in Japan: a case-control study of childhood leukemia and residential power-frequency magnetic fields in Japan, Int J Cancer. 2006 Aug 1;119(3):643-50 [View Comments and Links [H+]

Kan P et al, (January 2008) Cellular phone use and brain tumor: a meta-analysis, J Neurooncol. 2008 Jan;86(1):71-8. [H*]

Kan, P., Simonsen, S.E., Lyon, J.L. & Kestle, J.R.W. (2008) Cellular phone use and brain tumor: a meta-analysis. Journal of neuro-oncology, 86, 71–78. [H+]

Kapdi, M., Hoskote, S. & Joshi, S.R. (2008) Health hazards of mobile phones: an Indian perspective. JAPI, 56, 893–97. [H+]

Kaplan, S.B. (2000) Health Effects of Electromagnetic Fields: The State of the Science and Government Response. The Electricity Journal, 13, 25–33. [H*]

Karinen A et al, (February 2008) Mobile phone radiation might alter protein expression in human skin, BMC Genomics. 2008 Feb 11;9:77. [H+]

Kato M et al, (January 1994) Circularly polarized 50-Hz magnetic field exposure reduces pineal gland and blood melatonin concentrations of Long-Evans rats, Neurosci Lett. 1994 Jan 17;166(1):59-62. [W+]

Kaune WT, (December 2002) Thermal noise limit on the sensitivity of cellular membranes to power frequency electric and magnetic fields, Bioelectromagnetics. 2002 Dec;23(8):622-8. [H+]

Kavet R, Zaffanella LE, (September 2002) Contact voltage measured in residences: implications to the association between magnetic fields and childhood leukemia, Bioelectromagnetics. 2002 Sep;23(6):464-74. [View on Pubm [H+]

Keetley V et al, (June 2001) Neuropsychological sequelae of 50 Hz magnetic fields, Int J Radiat Biol. 2001 Jun;77(6):735-42. [H*]

Keetley V et al, (June 2001) Neuropsychological sequelae of 50 Hz magnetic fields, Int J Radiat Biol. 2001 Jun;77(6):735-42. [H*]

Keklikci U et al, (May 2008) The effect of extremely low frequency magnetic field on the conjunctiva and goblet cells, Curr Eye Res. 2008 May;33(5):441-6. [H+]

Kelsh MA, Sahl JD, (May 1997) Mortality among a cohort of electric utility workers, 1960-1991, Am J Ind Med. 1997 May;31(5):534-44. [H+]

Kheifets L et al, (July 2009) Extremely low frequency electric fields and cancer: Assessing the evidence, Bioelectromagnetics. 2009 Jul 31. [Epub ahead of print]. [H-]

Kheifets L et al, (July 2010) Exploring exposure-response for magnetic fields and childhood leukemia, J Expo Sci Environ Epidemiol. 2010 Jul 7. [Epub ahead of print]. [H*]

Kheifets L et al, (June 2008) Occupational electromagnetic fields and leukemia and brain cancer: an update to two meta-analyses, J Occup Environ Med. 2008 Jun;50(6):677-88. [H*]

Kheifets L et al, (October 2006) Childhood leukemia, electric and magnetic fields, and temporal trends, Bioelectromagnetics. 2006 Oct;27(7):545-52. [H*]

Kheifets L et al, (October 2006) Public Health Impact of Extremely Low-Frequency Electromagnetic Fields, Environ Health Perspect 114:1532-1537. [H+]

Kheifets L et al, (October 2010) A pooled analysis of extremely low-frequency magnetic fields and childhood brain tumors, Am J Epidemiol. 2010 Oct 1;172(7):752-61. Epub 2010 Aug 9. [H-]

Kheifets L et al, (September 2008) Future needs of occupational epidemiology of extremely low frequency (ELF) electric and magnetic fields (EMF): review and recommendations, Occup Environ Med. 2008 Sep 19. [Epub ahead of print] [View Comments [H*]

Khurana VG et al, (July 2010) Epidemiological evidence for a health risk from mobile phone base stations, Int J Occup Environ Health. 2010 Jul-Sep;16(3):263-7. [H+]

Khurana, V.G., Teo, C., Kundi, M., Hardell, L. & Carlberg, M. (2009) Cell phones and brain tumors: a review including the long-term epidemiologic data. Surgical neurology, 72, 205-214. [H+]

Kim BC, Park SO, (September 2010) Evaluation of RF electromagnetic field exposure levels from cellular base stations in Korea, Bioelectromagnetics. 2010 Sep;31(6):495-8. [H*]

Kim DW et al, (2008) Physiological effects of RF exposure on hypersensitive people by a cell phone, Conf Proc IEEE Eng Med Biol Soc. 2008;2008:2322-5. [H-]

Kim JY et al, (January 2008) In vitro assessment of clastogenicity of mobile-phone radiation (835 MHz) using the alkaline comet assay and chromosomal aberration test, Environ Toxicol. 2008 Jan 23 [Epub ahead of print]. [H*]

Kim JY et al, (January 2008) In vitro assessment of clastogenicity of mobile-phone radiation (835 MHz) using the alkaline comet assay and chromosomal aberration test, Environ Toxicol. 2008 Jan 23 [Epub ahead of print]. [H*]

Kim TH et al, (June 2008) Local exposure of 849 MHz and 1763 MHz radiofrequency radiation to mouse heads does not induce cell death or cell proliferation in brain, Exp Mol Med. 2008 Jun 30;40(3):294-303. [View on Pubme [W-]

Kim YW et al, (October 2008) Effects of 60 Hz 14 microT magnetic field on the apoptosis of testicular germ cell in mice, Bioelectromagnetics. 2008 Oct 6. [Epub ahead of print]. [H+]

Kirschvink JL et al, (August 1992) Magnetite biomineralization in the human brain, Proc Natl Acad Sci U S A. 1992 Aug 15;89(16):7683-7. [H*]

Kirschvink, J.L. (1982) Birds, bees and magnetism:: A new look at the old problem of magnetoreception. Trends in Neurosciences, 5, 160–167. [B+]

Kizilay, A., Ozturan, O., Erdem, T., Tayyar Kalcioglu, M. & Cem Miman, M. (2003) Effects of chronic exposure of electromagnetic fields from mobile phones on hearing in rats. Auris Nasus Larynx, 30, 239–245. [H+]

Klaeboe L et al, (April 2007) Use of mobile phones in Norway and risk of intracranial tumours, Eur J Cancer Prev. 2007 Apr;16(2):158-64. [H-]

Klaeboe L et al, (May 2005) Residential and occupational exposure to 50-Hz magnetic fields and brain tumours in Norway: a population-based study, Int J Cancer. 2005 May 20;115(1):137-41. [H*]

Kleinerman RA et al, (January 2005) Self-reported electrical appliance use and risk of adult brain tumors, Am J Epidemiol. 2005 Jan 15;161(2):136-46. [H-]

Kleinhaus, S., Pinshow, B., Frumkin, R., Ruppin, R. & Margaliot, M. (1995) Thermal effects of short radio waves on migrating birds. Ecological Applications, 5, 672–679. [B+]

Kliukiene J et al, (May 2004) Residential and occupational exposures to 50-Hz magnetic fields and breast cancer in women: a population-based study, Am J Epidemiol. 2004 May 1;159(9):852-61. [H+]

Koivisto M et al, (February 2000) Effects of 902 MHz electromagnetic field emitted by cellular telephones on response times in humans, Neuroreport. 2000 Feb 7;11(2):413-5. [H+]

Koivisto M et al, (June 2000) The effects of electromagnetic field emitted by GSM phones on working memory, Neuroreport. 2000 Jun 5;11(8):1641-3. [H+]

Kolodynski AA, Kolodynska VV, (February 1996) Motor and psychological functions of school children living in the area of the Skrunda Radio Location Station in Latvia, Sci Total Environ. 1996 Feb 2;180(1):87-93. [View o [H+]

Kowalczuk C et al, (October 2010) Absence of nonlinear responses in cells and tissues exposed to RF energy at mobile phone frequencies using a doubly resonant cavity, Bioelectromagnetics. 2010 Oct;31(7):556-65. [View o [H-]

Koylu H et al, (June 2006) Melatonin modulates 900 Mhz microwave-induced lipid peroxidation changes in rat brain, Toxicol Ind Health 2006 Jun;22(5):211-6. [W+]

Koziak AM et al, (January 2006) Light alters nociceptive effects of magnetic field shielding, Bioelectromagnetics. 2006 Jan;27(1):10-5. [H*]

Kramarenko AV, Tan U, (July 2003) Effects of high-frequency electromagnetic fields on human EEG: a brain mapping study, Int J Neurosci. 2003 Jul;113(7):1007-19. [H+]

Krause CM et al, (December 2000) Effects of electromagnetic fields emitted by cellular phones on the electroencephalogram during a visual working memory task, Int J Radiat Biol. 2000 Dec;76(12):1659-67. [View on Pubmed [H+]

Krause CM et al, (June 2006) Mobile phone effects on children's event-related oscillatory EEG during an auditory memory task, Int J Radiat Biol 2006 Jun;82(6):443-50. [H+]

Krause CM et al, (March 2000) Effects of electromagnetic field emitted by cellular phones on the EEG during a memory task, Neuroreport. 2000 Mar 20;11(4):761-4. [H+]

Krause CM et al, (May 2007) Effects of pulsed and continuous wave 902 MHz mobile phone exposure on brain oscillatory activity during cognitive processing, Bioelectromagnetics 2007 May;28(4):296-308. [H+]

Kristupaitis D et al, (May 1998) Electromagnetic field-induced stimulation of Bruton's tyrosine kinase, J Biol Chem. 1998 May 15;273(20):12397-401. [H+]

Kuhn S et al, (August 2007) Assessment Methods for Demonstrating Compliance With Safety Limits of Wireless Devices Used in Home and Office Environments, Electromagnetic Compatibility, 2007 August;49(3):519-525. [H*]

Kuhn S, Kuster N, (July 2006) Development of Procedures for the EMF Exposure Evaluation of Wireless Devices in Home and Office Environments Supplement 1: Close-to-Body and Base Station Wireless Data Communication Devices, Foundation for Resear [H+]

Kumar, G. (2010) CELL TOWER RADIATION. [W+]

Kumar, N. & Kumar, G. (2009a) Biological effects of cell tower radiation on human body. ISMOT, Delhi, India, 678–679. [W+]

Kumar, N. & Kumar, G. (2009b) Biological effects of cell tower radiation on human body. ISMOT, Delhi, India p. 678–679. [H+]

Kumar, V., Vats, R.P., Goyal, S., Kumar, S. & Pathak, P.P. (2008) Interaction of electromagnetic radiation with human body. Indian Journal of Radio & Space Physics, 37, 131–134. [H+]

Kundi M, (March 2009) The controversy about a possible relationship between mobile phone use and cancer, Environ Health Perspect. 2009 Mar;117(3):316-24. [H+]

Kundi M, Hutter HP, (March 2009) Mobile phone base stations-Effects on wellbeing and health, Pathophysiology. 2009 Mar 2. [Epub ahead of print]. [H*]

Kundi, M. & Hutter, H.P. (2009) Mobile phone base stations–Effects on wellbeing and health. Pathophysiology, 16, 123–135. [H+]

Kwon MS et al, (November 2007) Perception of the electromagnetic field emitted by a mobile phone, Bioelectromagnetics. 2007 Nov 20;29(2):154-159. [H-]

Lacy-Hulbert A et al, (October 1995) No effect of 60 Hz electromagnetic fields on MYC or beta-actin expression in human leukemic cells, Radiat Res. 1995 Oct;144(1):9-17. [H-]

Lagorio S et al, (1997) Mortality of plastic-ware workers exposed to radiofrequencies, Bioelectromagnetics. 1997;18(6):418-21. [H*]

Lagroye I, Poncy JL, (1998) Influences of 50-Hz magnetic fields and ionizing radiation on c-jun and c-fos oncoproteins, Bioelectromagnetics. 1998;19(2):112-6. [H+]

Lahkola A et al, (April 2007) Mobile phone use and risk of glioma in 5 North European countries, Int J Cancer. 2007 Apr 15;120(8):1769-75. [H+]

Lahkola A et al, (August 2008) Meningioma and mobile phone use--a collaborative case-control study in five North European countries, Int J Epidemiol. 2008 Aug 2. [Epub ahead of print]Click here to read. [View on Pubmed [H-]

Lahkola A et al, (May 2005) Selection bias due to differential participation in a case-control study of mobile phone use and brain tumors, Ann Epidemiol. 2005 May;15(5):321-5. [H*]

Lai H et al, (1994) Microwave irradiation affects radial-arm maze performance in the rat, Bioelectromagnetics. 1994;15(2):95-104. [W+]

Lai H et al, (1998) Acute exposure to a 60 Hz magnetic field affects rats' water-maze performance, Bioelectromagnetics. 1998;19(2):117-22. [W+]

Lai H et al, (May 1989) Low-level microwave irradiation and central cholinergic systems, Pharmacol Biochem Behav. 1989 May;33(1):131-8. [H+]

Lai H, (1996) Spatial learning deficit in the rat after exposure to a 60 Hz magnetic field, Bioelectromagnetics. 1996;17(6):494-6. [W+]

Lai H, (October 2004) Interaction of microwaves and a temporally incoherent magnetic field on spatial learning in the rat, Physiol Behav. 2004 Oct 15;82(5):785-9 [View [W+]

Lai H, (October 2004) Interaction of microwaves and a temporally incoherent magnetic field on spatial learning in the rat, Physiol Behav. 2004 Oct 15;82(5):785-9. [W+]

Lai H, Singh NP, (May 2004) Magnetic-field-induced DNA strand breaks in brain cells of the rat, Environ Health Perspect. 2004 May;112(6):687-94. [W+]

Lai, H. & Singh, N.P. (2004) Magnetic-field-induced DNA strand breaks in brain cells of the rat. Environmental Health Perspectives, 112, 687. [W+]

Lakshmanagowda, P.B., Supe, S.S., Viswanath, L. & Kunjar, S. (2009) Mobile phones and hearing-A review. Polish Journal of Medical Physics And Engineering, 15, 161-175. [H*]

Lalic H et al, (April 2001) Comparison of chromosome aberrations in peripheral blood lymphocytes from people occupationally exposed to ionizing and radiofrequency radiation, Acta Med Okayama. 2001 Apr;55(2):117-27. [Vi [H+]

Landgrebe M et al, (July 2008) Neuronal correlates of symptom formation in functional somatic syndromes: a fMRI study, Neuroimage. 2008 Jul 15;41(4):1336-44. [H*]

Landgrebe M et al, (March 2007) Altered cortical excitability in subjectively electrosensitive patients: results of a pilot study, J Psychosom Res. 2007 Mar;62(3):283-8. [H+]

Landgrebe M et al, (March 2008) Cognitive and neurobiological alterations in electromagnetic hypersensitive patients: results of a case-control study, Psychol Med. 2008 Mar 26;:1-11. [H+]

Lantow M et al, (September 2006) Comparative study of cell cycle kinetics and induction of apoptosis or necrosis after exposure of human mono mac 6 cells to radiofrequency radiation, Radiat Res. 2006 Sep;166(3):539-43. [H-]

Lascher, W. & Liburdy, R.P. (1998) Animal and cellular studies on carcinogenic effects of low frequency (50/60-Hz) magnetic fields. Mutation Research, 410, 185-220. [W*]

Lawrence AF, Adey WR, (1982) Nonlinear wave mechanisms in interactions between excitable tissue and electromagnetic fields, Neurol Res. 1982;4(1-2):115-53. [H*]

Lawrence AF, Adey WR, (1982) Nonlinear wave mechanisms in interactions between excitable tissue and electromagnetic fields, Neurol Res. 1982;4(1-2):115-53. [H*]

Lee BC et al, (January 2004) Effects of extremely low frequency magnetic field on the antioxidant defense system in mouse brain: a chemiluminescence study, J Photochem Photobiol B. 2004 Jan 23;73(1-2):43-8. [View on Pu [W+]

Lee GM et al, (January 2002) A nested case-control study of residential and personal magnetic field measures and miscarriages, Epidemiology. 2002 Jan;13(1):21-31. [H+]

Lee HJ et al, (November 2009) Lack of teratogenicity after combined exposure of pregnant mice to CDMA and WCDMA radiofrequency electromagnetic fields, Radiat Res. 2009 Nov;172(5):648-52. [W-]

Lee HJ et al, (October 2010) The lack of histological changes of CDMA cellular phone-based radio frequency on rat testis, Bioelectromagnetics. 2010 Oct;31(7):528-34. [W-]

Leena K et al, (February 2005) Intensity of mobile phone use and health compromising behaviours--how is information and communication technology connected to health-related lifestyle in adolescence?, J Adolesc. 2005 Feb;28(1):35-47 [View Comme [H*]

Leger, J. & Larochelle, J. (2006) On the importance of radiative heat exchange during nocturnal flight in birds. Journal of experimental biology, 209, 103–114. [B*]

Leitgeb N et al, (May 2005) Does "electromagnetic pollution" cause illness? An inquiry among Austrian general practitioners, Wien Med Wochenschr. 2005 May;155(9-10):237-41. [H+]

Leitgeb N, Schrottner J, (September 2003) Electrosensibility and electromagnetic hypersensitivity, Bioelectromagnetics. 2003 Sep;24(6):387-94. [H*]

Lerchl A et al, (April 2008) Effects of mobile phone electromagnetic fields at nonthermal SAR values on melatonin and body weight of Djungarian hamsters (Phodopus sungorus), J Pineal Res. 2008 Apr;44(3):267-72. [View o [W+]

Leszczynski D et al, (May 2002) Non-thermal activation of the hsp27/p38MAPK stress pathway by mobile phone radiation in human endothelial cells: molecular mechanism for cancer- and blood-brain barrier-related effects, Differentiation. 2002 May [H+]

Leszczynski D, (February 2005) Rapporteur report: cellular, animal and epidemiological studies of the effects of static magnetic fields relevant to human health, Prog Biophys Mol Biol. 2005 Feb-Apr;87(2-3):247-53. [Vie [H*]

Levallois P et al, (August 2002) Study of self-reported hypersensitivity to electromagnetic fields in California, Environ Health Perspect. 2002 Aug;110 Suppl 4:619-23. [H+]

Levallois P et al, (October 2001) Effects of electric and magnetic fields from high-power lines on female urinary excretion of 6-sulfatoxymelatonin, Am J Epidemiol. 2001 Oct 1;154(7):601-9. [H+]

Levallois P, (August 2002) Hypersensitivity of human subjects to environmental electric and magnetic field exposure: a review of the literature, Environ Health Perspect. 2002 Aug;110 Suppl 4:613-8. [H*]

Levitt, B.B. & Lai, H. (2010) Biological effects from exposure to electromagnetic radiation emitted by cell tower base stations and other antenna arrays. Environmental Reviews, 18, 369–395. [H+]

Lewy H et al, (June 2003) Magnetic field (50 Hz) increases N-acetyltransferase, hydroxy-indole-O-methyltransferase activity and melatonin release through an indirect pathway, Int J Radiat Biol. 2003 Jun;79(6):431-5. [V [H+]

Li CY et al, (January 1997) Residential exposure to 60-Hertz magnetic fields and adult cancers in Taiwan, Epidemiology. 1997 Jan;8(1):25-30. [H+]

Li DK et al, (January 2002) A population-based prospective cohort study of personal exposure to magnetic fields during pregnancy and the risk of miscarriage, Epidemiology. 2002 Jan;13(1):9-20. [H+]

Li DK et al, (January 2010) Exposure to magnetic fields and the risk of poor sperm quality, Reprod Toxicol. 2010 Jan;29(1):86-92. Epub 2009 Nov 6. [H+]

Li L et al, (December 2005) Pulsed electric field exposure of insulin induces anti-proliferative effects on human hepatocytes, Bioelectromagnetics. 2005 Dec;26(8):639-47. [H+]

Li M et al, (March 2008) Elevation of plasma corticosterone levels and hippocampal glucocorticoid receptor translocation in rats: a potential mechanism for cognition impairment following chronic low-power-density microwave exposure, J Radiat R [W*]

Li M et al, (March 2008) Elevation of plasma corticosterone levels and hippocampal glucocorticoid receptor translocation in rats: a potential mechanism for cognition impairment following chronic low-power-density microwave exposure, J Radiat R [W*]

Li X et al, (June 2001) Effects of low frequency pulsed electric field on insulin studied by fluorescent spectrum, Guang Pu Xue Yu Guang Pu Fen Xi. 2001 Jun;21(3):406-8. [H+]

Liakouris, A.G.J. (1998) Radiofrequency (RF) Sickness in the Lilienfield study: An effect of Modulated Microwaves? Archives of Environmental Health, 53, 236-238. [H+]

Liburdy RP et al, (November 1993) Experimental evidence for 60 Hz magnetic fields operating through the signal transduction cascade. Effects on calcium influx and c-MYC mRNA induction, FEBS Lett. 1993 Nov 22;334(3):301-8 [View Comments and Lin [H+]

Lin JC, Wang Z, (June 2007) Hearing of microwave pulses by humans and animals: effects, mechanism, and thresholds, Health Phys. 2007 Jun;92(6):621-8 [W*]

Lin JC, Wang Z, (June 2007) Hearing of microwave pulses by humans and animals: effects, mechanism, and thresholds, Health Phys. 2007 Jun;92(6):621-8. [W*]

Lindstrom E et al, (August 1993) Intracellular calcium oscillations induced in a T-cell line by a weak 50 Hz magnetic field, J Cell Physiol. 1993 Aug;156(2):395-8. [H+]

Linet MS et al, (July 1997) Residential exposure to magnetic fields and acute lymphoblastic leukemia in children, N Engl J Med. 1997 Jul 3;337(1):1-7. [H-]

Litmanen, T. & Tuikkanen, A. (2008) Global sense of risk: Media reporting on scientific studies and potential risks of mobile phones. Journal of Research and Practice in Information Technology, 40, 71-90. [H+]

Liu T et al, (March 2008) Anxiogenic effect of chronic exposure to extremely low frequency magnetic field in adult rats, Neurosci Lett. 2008 Mar 21;434(1):12-7. [W*]

Liu T et al, (March 2008) Chronic exposure to low-intensity magnetic field improves acquisition and maintenance of memory, Neuroreport. 2008 Mar 25;19(5):549-52. [H+]

Liu Y et al, (January 2005) Magnetic field effect on singlet oxygen production in a biochemical system, Chem Commun (Camb). 2005 Jan 14;(2):174-6. [H+]

Loberg LI et al, (August 1999) Gene expression in human breast epithelial cells exposed to 60 Hz magnetic fields, Carcinogenesis. 1999 Aug;20(8):1633-6. [H*]

Loberg LI et al, (May 2000) Expression of cancer-related genes in human cells exposed to 60 Hz magnetic fields, Radiat Res. 2000 May;153(5 Pt 2):679-84. [H-]

Lohmann, K.J. & Johnsen, S. (2000) The neurobiology of magnetoreception in vertebrate animals. Trends in neurosciences, 23, 153–159. [W*]

London SJ et al, (November 1991) Exposure to residential electric and magnetic fields and risk of childhood leukemia, Am J Epidemiol. 1991 Nov 1;134(9):923-37. [H+]

Lonn S et al, (January 2004) Incidence trends of adult primary intracerebral tumors in four Nordic countries, Int J Cancer. 2004 Jan 20;108(3):450-5. [H*]

Lonn S et al, (March 2005) Long-term mobile phone use and brain tumor risk, Am J Epidemiol. 2005 Mar 15;161(6):526-35. [H-]

Lonn S et al, (November 2004) Mobile phone use and the risk of acoustic neuroma, Epidemiology. 2004 Nov;15(6):653-9. [H+]

Lonn S et al, (October 2006) Mobile phone use and risk of parotid gland tumor, Am J Epidemiol. 2006 Oct 1;164(7):637-43. Epub 2006 Jul 3. [H-]

Lönn, S., Ahlbom, A., Hall, P. & Feychting, M. (2005) Long-term mobile phone use and brain tumor risk. American journal of epidemiology, 161, 526. [H-]

Lopez-Berenguer C et al, (November 2007) Effects of microwave cooking conditions on bioactive compounds present in broccoli inflorescences, J Agric Food Chem. 2007 Nov 28;55(24):10001-7. [P+]

Lopez-Martin E et al, (May 2009) The action of pulse-modulated GSM radiation increases regional changes in brain activity and c-Fos expression in cortical and subcortical areas in a rat model of picrotoxin-induced seizure proneness, J Neurosci [W+]

Loscher W et al, (July 1993) Tumor promotion in a breast cancer model by exposure to a weak alternating magnetic field, Cancer Lett. 1993 Jul 30;71(1-3):75-81. [H+]

Lowenthal RM et al, (September 2007) Residential exposure to electric power transmission lines and risk of lymphoproliferative and myeloproliferative disorders: a case-control study, Intern Med J. 2007 Sep;37(9):614-9. [H+]

Lupke M et al, (September 2004) Cell activating capacity of 50 Hz magnetic fields to release reactive oxygen intermediates in human umbilical cord blood-derived monocytes and in Mono Mac 6 cells, Free Radic Res. 2004 Sep;38(9):985-93 [View Com [H+]

Luria R et al, (November 2008) Cognitive effects of radiation emitted by cellular phones: The influence of exposure side and time, Bioelectromagnetics. 2008 Nov 17;30(3):198-204. [Epub ahead of print]. [H+]

Luukkonen J et al, (December 2008) Enhancement of chemically induced reactive oxygen species production and DNA damage in human SH-SY5Y neuroblastoma cells by 872MHz radiofrequency radiation, Mutat Res. 2008 Dec 24. [Epub ahead of print] [View [H*]

Lyle DB et al, (1997) Intracellular calcium signaling by Jurkat T-lymphocytes exposed to a 60 Hz magnetic field, Bioelectromagnetics. 1997;18(6):439-45. [H-]

Lyskov E et al, (November 2001) Int J Psychophysiol. 2001 Nov;42(3):233-41, Int J Psychophysiol. 2001 Nov;42(3):233-41. [H+]

Lyskov E et al, (October 2001) Provocation study of persons with perceived electrical hypersensitivity and controls using magnetic field exposure and recording of electrophysiological characteristics, Bioelectromagnetics. 2001 Oct;22(7):457-62 [H+]

Madhukara, J., Kumaran, M.S. & Abraham, A. (2008) Cell phone dermatitis. Indian Journal of Dermatology, Venereology and Leprology, 74, 500–501. [H+]

Mailankot M et al, (2009) Radio frequency electromagnetic radiation (RF-EMR) from GSM (0.9/1.8GHz) mobile phones induces oxidative stress and reduces sperm motility in rats, Clinics (Sao Paulo). 2009;64(6):561-5. [View [W+]

Malagoli C et al, (March 2010) Risk of hematological malignancies associated with magnetic fields exposure from power lines: a case-control study in two municipalities of northern Italy, Environ Health. 2010 Mar 30;9:16 [View Comments and Link [H+]

Manti L et al, (May 2008) Effects of Modulated Microwave Radiation at Cellular Telephone Frequency (1.95 GHz) on X-Ray-Induced Chromosome Aberrations in Human Lymphocytes In Vitro, Radiat Res. 2008 May;169(5):575-83. [[H+]

Manucy, T.K., Bennett, R.A., Greenacre, C.B., Roberts, R.E., Schumacher, J. & Sharon, L.D. (1998) Squamous Cell Carcinoma of the Mandibular Beak in a Buffon?s Macaw (Ara ambigua). Journal of Avian Medicine and Surgery, 12, 158-166. [H*]

Manville, A.M. (2008) Towers, turbines, power lines, and buildings—steps being taken by the US Fish and Wildlife Service to avoid or minimize take of migratory birds at these structures. Tundra to tropics: connecting birds, habitats and people. Proceedings of the 4th International Partners in Flight Conference p. 13–16. [B+]

Mariucci G et al, (August 2010) Brain DNA damage and 70-kDa heat shock protein expression in CD1 mice exposed to extremely low frequency magnetic fields, Int J Radiat Biol. 2010 Aug;86(8):701-10. [W+]

Markova E et al, (September 2005) Microwaves from GSM mobile telephones affect 53BP1 and gamma-H2AX foci in human lymphocytes from hypersensitive and healthy persons, Environ Health Perspect. 2005 Sep;113(9):1172-7. [V [H+]

Martínez, A.B. (2003) The effects of microwave radiation on the wildlife. Preliminary results. [W+]

Maskarinec G et al, (1994) Investigation of increased incidence in childhood leukemia near radio towers in Hawaii: preliminary observations, J Environ Pathol Toxicol Oncol. 1994;13(1):33-7. [H+]

Maskey D et al, (February 2010) Effect of 835 MHz radiofrequency radiation exposure on calcium binding proteins in the hippocampus of the mouse brain, Brain Res. 2010 Feb 8;1313:232-41. Epub 2009 Dec 5. [View on Pubmed [W+]

Maskey D et al, (July 2010) Chronic 835-MHz radiofrequency exposure to mice hippocampus alters the distribution of calbindin and GFAP immunoreactivity, Brain Res. 2010 Jul 30;1346:237-46. Epub 2010 Jun 17. [View on Pub [W+]

Maslanyj MP et al, (August 2005) Investigation and Identification of Sources of Residential Magnetic Field Exposures in the United Kingdom Childhood Cancer Study (UKCCS), HPA-RPD-005 - ISBN 0 85951 564 8. [H*]

Maslanyj MP et al, (March 2007) Investigation of the sources of residential power frequency magnetic field exposure in the UK Childhood Cancer Study, J Radiol Prot. 2007 Mar;27(1):41-58. [H*]

Masuda H et al, (July 2009) Effects of 915 MHz electromagnetic-field radiation in TEM cell on the blood-brain barrier and neurons in the rat brain, Radiat Res. 2009 Jul;172(1):66-73. [W-]

Mathur R, (2008) Effect of chronic intermittent exposure to AM radiofrequency field on responses to various types of noxious stimuli in growing rats, Electromagn Biol Med. 2008;27(3):266-76. [W+]

Matronchik AY, Belyaev IY et al, (2008) Mechanism for combined action of microwaves and static magnetic field: slow non uniform rotation of charged nucleoid, Electromagn Biol Med. 2008;27(4):340-54. [H+]

Mazor R et al, (January 2008) Increased levels of numerical chromosome aberrations after in vitro exposure of human peripheral blood lymphocytes to radiofrequency electromagnetic fields for 72 hours, Radiat Res. 2008 Jan;169(1):28-37 [View Com [H+]

McBride ML et al, (May 1999) Power-frequency electric and magnetic fields and risk of childhood leukemia in Canada, Am J Epidemiol. 1999 May 1;149(9):831-42. [H-]

McCann J et al, (August 1998) The genotoxic potential of electric and magnetic fields: an update, Mutat Res. 1998 Aug;411(1):45-86. [H*]

McCann J et al, (July 1993) A critical review of the genotoxic potential of electric and magnetic fields, Mutat Res. 1993 Jul;297(1):61-95. [H-]

McIntosh RL, Anderson V, (September 2010) SAR versus S(inc): What is the appropriate RF exposure metric in the range 1-10 GHz? Part II: Using complex human body models, [H*]

McMahan S et al, (January 1994) Depressive symptomatology in women and residential proximity to high-voltage transmission lines, Am J Epidemiol. 1994 Jan 1;139(1):58-63. [H-]

McNamee DA et al, (February 2009) A literature review: the cardiovascular effects of exposure to extremely low frequency electromagnetic fields, Int Arch Occup Environ Health. 2009 Feb 17. [Epub ahead of print]. [View [H*]

McNamee JP, Chauhan V., (September 2009) Radiofrequency radiation and gene/protein expression: a review, Radiat Res. 2009 Sep;172(3):265-87. [H*]

McQuade JM et al, (May 2009) Radiofrequency-radiation exposure does not induce detectable leakage of albumin across the blood-brain barrier, Radiat Res. 2009 May;171(5):615-21. [H-]

Mee T et al, (April 2009) Occupational exposure of UK adults to ELF magnetic fields, Occup Environ Med. 2009 Apr 20. [Epub ahead of print]. [H*]

Meo SA, Al-Drees AM, (2005) Mobile phone related-hazards and subjective hearing and vision symptoms in the Saudi population, Int J Occup Med Environ Health. 2005;18(1):53-7. [H+]

Meo, S.A. & Al Dreess, A.M. (2005) Mobile phone related hazards and subjective hearing and vision symptoms in the Saudi population. International Journal of Occupational Medicine and Environmental Health, 18, 45-49. [H+]

Meral I et al, (September 2007) Effects of 900-MHz electromagnetic field emitted from cellular phone on brain oxidative stress and some vitamin levels of guinea pigs, Brain Res. 2007 Sep 12;1169:120-4. Epub 2007 Jul 17 [View Comments and Links [W+]

Merzenich H et al, (October 2008) Childhood Leukemia in Relation to Radio Frequency Electromagnetic Fields in the Vicinity of TV and Radio Broadcast Transmitters, Am J Epidemiol. 2008 Oct 3. [Epub ahead of print]. [Vie [H-]

Michaelis J et al, (January 1998) Combined risk estimates for two German population-based case-control studies on residential magnetic fields and childhood acute leukemia, Epidemiology. 1998 Jan;9(1):92-4.. [View on Pu [H+]

Michaelis J et al, (March 1997) Childhood leukemia and electromagnetic fields: results of a population-based case-control study in Germany, Cancer Causes Control. 1997 Mar;8(2):167-74. [H+]

Michelozzi P et al, (June 2002) Adult and childhood leukemia near a high-power radio station in Rome, Italy, Am J Epidemiol. 2002 Jun 15;155(12):1096-103. [H+]

Michelozzi P et al, (November 2001) Leukemia mortality and incidence of infantile leukemia near the Vatican Radio Station of Rome, Epidemiol Prev. 2001 Nov-Dec;25(6):249-55. [H+]

Mild KH et al, (2007) Pooled analysis of two Swedish case-control studies on the use of mobile and cordless telephones and the risk of brain tumours diagnosed during 1997-2003, Int J Occup Saf Ergon. 2007;13(1):63-71. [H+]

Mild KH et al, (April 2009) Background ELF magnetic fields in incubators: A factor of importance in cell culture work, Cell Biol Int. 2009 Apr 23. [Epub ahead of print]. [H*]

Milham S, (November 2009) Most cancer in firefighters is due to radio-frequency radiation exposure not inhaled carcinogens, Med Hypotheses. 2009 Nov;73(5):788-9. Epub 2009 May 22. [H*]

Milham S, Morgan LL, (May 2008) A new electromagnetic exposure metric: High frequency voltage transients associated with increased cancer incidence in teachers in a california school, Am J Ind Med. 2008 May 29. [Epub ahead of print] [View Comm [H+]

Milham S, Ossiander EM, (March 2001) Historical evidence that residential electrification caused the emergence of the childhood leukemia peak, Med Hypotheses. 2001 Mar;56(3):290-5. [H+]

Milham, S. (2009) Most cancer in firefighters is due to radio-frequency radiation exposure not inhaled carcinogens. Medical hypotheses, 73, 788–789. [H+]

Miller SC, Furniss MJ, (December 1998) Bruton's tyrosine kinase activity and inositol 1,4,5-trisphosphate production are not altered in DT40 lymphoma B cells exposed to power line frequency magnetic fields, J Biol Chem. 1998 Dec 4;273(49):3261 [H+]

Misra, A. & Gupta, D.C. (2007) Microwave and EMR Pollution Due to Mobile Towers and Mobile Phones [H+]

Mixson, T.A., Abramson, C.I., Nolf, S.L., Johnson, G.A., Serrano, E. & Wells, H. (2009) Effect of GSM Cellular Phone Radiation on the Behavior of Honey Bees (Apis mellifera). Science Of Bee Culture, 22. [Es-]

Miyakoshi J et al, (February 2000) Suppression of heat-induced HSP-70 by simultaneous exposure to 50 mT magnetic field, Life Sci. 2000 Feb 18;66(13):1187-96. [H+]

Miyakoshi J, (February 2005) Effects of static magnetic fields at the cellular level, Prog Biophys Mol Biol. 2005 Feb-Apr;87(2-3):213-23. [H+]

Mohammadi, S., Taghavi-Dehaghani, M., Gharaati, M.R., Masoomi, R. & Ghiassi-Nejad, M. (2006) Adaptive response of blood lymphocytes of inhabitants residing in high background radiation areas of ramsar-micronuclei, apoptosis and comet assays. Journal of radiation research, 609140008. [H+]

Morabito C et al, (February 2010) Modulation of redox status and calcium handling by extremely low frequency electromagnetic fields in C2C12 muscle cells: A real-time, single-cell approach, Free Radic Biol Med. 2010 Feb 15;48(4):579-89. Epub 2 [H+]

Morgan LL, (April 2009) Estimating the risk of brain tumors from cellphone use: Published case-control studies, Pathophysiology. 2009 Apr 6. [Epub ahead of print]Click here to read. [H+]

Morgan RW et al, (March 2000) Radiofrequency exposure and mortality from cancer of the brain and lymphatic/hematopoietic systems, Epidemiology. 2000 Mar;11(2):118-27. [H-]

Morgan, L.L. (2006) Mobile phone use and risk of glioma in adults: Study has many flaws. British Medical Journal, 332, 1035. [H+]

Mortazavi SM et al, (May 2007) Prevalence of subjective poor health symptoms associated with exposure to electromagnetic fields among university students, Bioelectromagnetics. 2007 May;28(4):326-30. [H-]

Moszczynski P et al, (1999) The effect of various occupational exposures to microwave radiation on the concentrations of immunoglobulins and T lymphocyte subsets, Wiad Lek. 1999;52(1-2):30-4. [H+]

Moulder JE, (1998) Power-frequency fields and cancer, Crit Rev Biomed Eng. 1998;26(1-2):1-116. [H*]

Mousavy SJ et al, (April 2009) Effects of mobile phone radiofrequency on the structure and function of the normal human hemoglobin, Int J Biol Macromol. 2009 Apr 1;44(3):278-85. [H+]

Mousavy, S.J., Riazi, G.H., Kamarei, M., Aliakbarian, H., Sattarahmady, N., Sharifizadeh, A., Safarian, S., Ahmad, F. & Moosavi-Movahedi, A.A. (2009) Effects of mobile phone radiofrequency on the structure and function of the normal human hemoglobin. International journal of biological macromolecules, 44, 278-285. [H+]

Mudie, N.Y., Gusev, B.I., Pivina, L.M., Schoemaker, M.J., Rijinkova, O.N., Apsalikov, K.N. & Swerdlow, A.J. (2007) Sex Ratio in the Offspring of Parents with Chronic Radiation Exposure from Nuclear Testing in Kazakhstan. Radiation research, 168, 600-607. [H+]

Munshi, A. & Jalali, R. (2002) Cellular phones and their hazards: the current evidence. The National medical journal of India, 15, 275-277. [H+]

Murphy JC et al, (March 1993) International Commission for Protection Against Environmental Mutagens and Carcinogens. Power frequency electric and magnetic fields: a review of genetic toxicology, Mutat Res. 1993 Mar;296(3):221-40 [View Comment [H*]

Muscat JE et al, (April 2002) Handheld cellular telephones and risk of acoustic neuroma, Neurology. 2002 Apr 23;58(8):1304-6. [H-]

Muscat JE et al, (December 2000) Handheld cellular telephone use and risk of brain cancer, JAMA. 2000 Dec 20;284(23):3001-7. [H-]

Myers A et al, (December 1990) Childhood cancer and overhead powerlines: a case-control study, Br J Cancer. 1990 Dec;62(6):1008-14. [H-]

Myung SK et al, (November 2009) Mobile phone use and risk of tumors: a meta-analysis, J Clin Oncol. 2009 Nov 20;27(33):5565-72. Epub 2009 Oct 13. [H+]

Nagle, J.C. (2009) ESSAY: CELL PHONE TOWERS AS VISUAL POLLUTION. ND JL Ethics & Pub Pol?y, 23, 537–673. [H*]

Narayanan SN et al, (May 2010) Effect of radio-frequency electromagnetic radiations (RF-EMR) on passive avoidance behaviour and hippocampal morphology in Wistar rats, Ups J Med Sci. 2010 May;115(2):91-6. [View on Pubme [W+]

Navarro EA et al, (December 2003) The Microwave Syndrome: A Preliminary Study in Spain, Electromagn Biol Med 22(2-3): 161-169. [H+]

Navarro, E.A., Segura, J., Portolés, M. & Gómez-Perretta de Mateo, C. (2003) The microwave syndrome: a preliminary study in Spain. Electromagnetic biology and medicine, 22, 161–169. [H+]

Navas-Acien A et al, (December 2002) Interactive effect of chemical substances and occupational electromagnetic field exposure on the risk of gliomas and meningiomas in Swedish men, Cancer Epidemiol Biomarkers Prev. 2002 Dec;11(12):1678-83 [Vi [H*]

Nicholls, B. & Racey, P.A. (2007) Bats avoid radar installations: Could electromagnetic fields deter bats from colliding with wind turbines. PloS One, 2, e297. [H+]

Nieto-Hernandez R et al, (November 2008) Can evidence change belief? Reported mobile phone sensitivity following individual feedback of an inability to discriminate active from sham signals, J Psychosom Res. 2008 Nov;65(5):453-60 [View Comment [H*]

Nikolova T et al, (October 2005) Electromagnetic fields affect transcript levels of apoptosis-related genes in embryonic stem cell-derived neural progenitor cells, FASEB J. 2005 Oct;19(12):1686-8. [H+]

Nittby H et al, (2008) Radiofrequency and extremely low-frequency electromagnetic field effects on the blood-brain barrier, Electromagn Biol Med. 2008;27(2):103-26. [H+]

Nittby H et al, (August 2009) Increased blood-brain barrier permeability in mammalian brain 7 days after exposure to the radiation from a GSM-900 mobile phone, Pathophysiology. 2009 Aug;16(2-3):103-12. Epub 2009 Apr 2. [W+]

Nittby H et al, (November 2007) Cognitive impairment in rats after long-term exposure to GSM-900 mobile phone radiation, Bioelectromagnetics. 2007 Nov 28 [Epub ahead of print]. [W+]

Nittby, H., Brun, A., Eberhardt, J., Malmgren, L., Persson, B.R.R. & Salford, L.G. (2009) Increased blood-brain barrier permeability in mammalian brain 7 days after exposure to the radiation from a GSM-900 mobile phone. Pathophysiology, 16, 103–112. [H+]

Noonan CW et al, (February 2002) Occupational exposure to magnetic fields in case-referent studies of neurodegenerative diseases, Scand J Work Environ Health. 2002 Feb;28(1):42-8. [H+]

Novikov VV et al, (March 2009) Effect of weak combined static and extremely low-frequency alternating magnetic fields on tumor growth in mice inoculated with the Ehrlich ascites carcinoma, Bioelectromagnetics. 2009 Mar 6. [Epub ahead of print] [W+]

Ntzouni, M.P., Stamatakis, A., Stylianopoulou, F. & Margaritis, L.H. (2010) Short-term memory in mice is affected by mobile phone radiation. Pathophysiology. [W+]

Nylund R, Leszcynski D, (September 2006) Mobile phone radiation causes changes in gene and protein expression in human endothelial cell lines and the response seems to be genome- and proteome-dependent, Proteomics 2006 Sep;6(17):4769-80 [View [H+]

O'Sullivan, J. (2009) Electromagnetic Photon Waves. [H*]

Oberfeld G et al, (October 2004) The Microwave Syndrome - Further Aspects of a Spanish Study, Conference Proceedings. [H+]

Oberfeld, G., Enrique, N.A., Manuel, P., Ceferino, M. & Claudio, G.P. (2004) The Microwave Syndrome: Further Aspects of a Spanish Study. Presented at an International Conference in Kos (Greece) [H+]

Oberto G et al, (September 2007) Carcinogenicity study of 217 Hz pulsed 900 MHz electromagnetic fields in Pim1 transgenic mice, Radiat Res. 2007 Sep;168(3):316-26. [W-]

O'Connor RP et al, (July 2010) Exposure to GSM RF fields does not affect calcium homeostasis in human endothelial cells, rat pheocromocytoma cells or rat hippocampal neurons, PLoS One. 2010 Jul 27;5(7):e11828. [View on [H-]

Odaci E et al, (August 2008) Effects of prenatal exposure to a 900 Mhz electromagnetic field on the dentate gyrus of rats: a stereological and histopathological study, Brain Res. 2008 Aug 16. [Epub ahead of print]. [Vi [W+]

Oftedal G et al, (May 2000) Symptoms experienced in connection with mobile phone use, Occup Med (Lond). 2000 May;50(4):237-45. [H+]

Oftedal G et al, (May 2007) Mobile phone headache: a double blind, sham-controlled provocation study, Cephalalgia. 2007 May;27(5):447-55. [H-]

Oktay MF, Dasdag S, (2006) Effects of intensive and moderate cellular phone use on hearing function, Electromagn Biol Med. 2006;25(1):13-21. [H+]

Oktem F et al, (July 2005) Oxidative damage in the kidney induced by 900-MHz-emitted mobile phone: protection by melatonin, Arch Med Res. 2005 Jul-Aug;36(4):350-5. [H+]

Okudan N et al, (2010) Effects of long-term 50 Hz magnetic field exposure on the micro nucleated polychromatic erythrocyte and blood lymphocyte frequency and argyrophilic nucleolar organizer regions in lymphocytes of mice, Neuro Endocrinol Let [W-]

Okudan N et al, (2010) Effects of long-term 50 Hz magnetic field exposure on the micro nucleated polychromatic erythrocyte and blood lymphocyte frequency and argyrophilic nucleolar organizer regions in lymphocytes of mice, Neuro Endocrinol Let [W-]

Olsen JH et al, (October 1993) Residence near high voltage facilities and risk of cancer in children, BMJ. 1993 Oct 9;307(6909):891-5. [H+]

Oral B et al, (November 2006) Endometrial apoptosis induced by a 900-MHz mobile phone: preventive effects of vitamins E and C, Adv Ther. 2006 Nov-Dec;23(6):957-73. [H+]

Orendacova J et al, (March 2009) Immunohistochemical Study of Postnatal Neurogenesis After Whole-body Exposure to Electromagnetic Fields: Evaluation of Age- and Dose-Related Changes in Rats, Cell Mol Neurobiol. 2009 Mar 21. [Epub ahead of prin [H+]

Orjan, H. (2007) Radio, TV towers linked to increased risk of melanoma, www.foodconsumer.org ________________ [H+]

Oschman, J.L. (2005) Energy and the healing response. Journal of Bodywork and Movement Therapies, 9, 3-15. [H+]

others. (2009) Acute myeloid leukemia following radioactive iodine therapy for papillary carcinoma of the thyroid. Turkish Journal of Hematology, 26, 97-99. [H+]

Otitoloju AA et al, (October 2009) Preliminary study on the induction of sperm head abnormalities in mice, Mus musculus, exposed to radiofrequency radiations from global system for mobile communication base stations, Bull Environ Contam Toxico [W+]

Ouellet-Hellstrom R, Stewart WF, (November 1993) Miscarriages among female physical therapists who report using radio- and microwave-frequency electromagnetic radiation, Am J Epidemiol. 1993 Nov 15;138(10):775-86. [Vie [H+]

Ozguner F et al, (August 2005) Comparative analysis of the protective effects of melatonin and caffeic acid phenethyl ester (CAPE) on mobile phone-induced renal impairment in rat, Mol Cell Biochem. 2005 Aug;276(1-2):31-7 [View Comments and Lin [W+]

Ozguner F et al, (September 2004) Prevention of mobile phone induced skin tissue changes by melatonin in rat: an experimental study, Toxicol Ind Health. 2004 Sep;20(6-10):133-9. [W+]

Paglialonga A et al, (May 2008) Analysis of time-frequency fine structure of transiently evoked otoacoustic emissions to study the effects of exposure to GSM radiofrequency fields, J Acoust Soc Am. 2008 May;123(5):3855 [View Comments and Links [H-]

Palumbo R et al, (September 2008) Exposure to 900 MHz Radiofrequency Radiation Induces Caspase 3 Activation in Proliferating Human Lymphocytes, Radiat Res. 2008 Sep;170(3):327-34. [H+]

Panagopoulos D et al, (2004) Effect of GSM 900-MHz Mobile Phone radiation on the reproductive capacity of Drosophila melanogaster, Electromagn Biol Med 23(1): 29-43. [W+]

Panagopoulos D et al, (January 2007) Cell death induced by GSM 900-MHz and DCS 1800-MHz mobile telephony radiation, Mutat Res. 2007 Jan 10;626(1-2):69-78. [H+]

Panagopoulos DJ, Margaritis LH, (May 2010) The identification of an intensity 'window' on the bioeffects of mobile telephony radiation, Int J Radiat Biol. 2010 May;86(5):358-66. [H+]

Panda NK et al, (February 2010) Audiologic disturbances in long-term mobile phone users, J Otolaryngol Head Neck Surg. 2010 Feb 1;39(1):5-11. [H+]

Papageorgiou CC et al, (April 2006) Acute mobile phone effects on pre-attentive operation, Neurosci Lett. 2006 Apr 10-17;397(1-2):99-103. [H+]

Park SK et al, (August 2004) Ecological study on residences in the vicinity of AM radio broadcasting towers and cancer death: preliminary observations in Korea, Int Arch Occup Environ Health. 2004 Aug;77(6):387-94. [Vi [H+]

Pathak, C.M., Avti, P.K., KUMAR, S., Khanduja, K.L. & Sharma, S.C. (2007) Whole body exposure to low-dose gamma radiation promotes kidney antioxidant status in Balb/c mice. Journal of radiation research, 703020009. [H+]

Patruno A et al, (October 2009) Extremely low frequency electromagnetic fields modulate expression of inducible nitric oxide synthase, endothelial nitric oxide synthase and cyclooxygenase-2 in the human keratinocyte cell line HaCat: potential [H+]

Pattazhy, S. Electromagnetic Radiation (EMR) Clashes With Honeybees. [Es+]

Pavicic I, Trosic I, (August 2008) In vitro testing of cellular response to ultra high frequency electromagnetic field radiation, Toxicol In Vitro. 2008 Aug;22(5):1344-8. [H+]

Pearce MS et al, (September 2007) Paternal occupational exposure to electro-magnetic fields as a risk factor for cancer in children and young adults: a case-control study from the North of England, Pediatr Blood Cancer. 2007 Sep;49(3):280-6 [V [H+]

Perentos N et al, (2008) The effect of GSM-like ELF radiation on the alpha band of the human resting EEG, Conf Proc IEEE Eng Med Biol Soc. 2008;2008:5680-3. [H+]

Perez FP et al, (April 2008) Electromagnetic field therapy delays cellular senescence and death by enhancement of the heat shock response, Exp Gerontol. 2008 Apr;43(4):307-16. [H+]

Perez-Castejon C et al, (December 2009) Exposure to ELF-pulse modulated X band microwaves increases in vitro human astrocytoma cell proliferation, Histol Histopathol. 2009 Dec;24(12):1551-61. [H+]

Perez-Castejon C et al, (December 2009) Exposure to ELF-pulse modulated X band microwaves increases in vitro human astrocytoma cell proliferation, Histol Histopathol. 2009 Dec;24(12):1551-61. [H+]

Perry S et al, (May 1989) Power frequency magnetic field; depressive illness and myocardial infarction, Public Health. 1989 May;103(3):177-80. [H+]

Persinger MA, (2006) A potential multiple resonance mechanism by which weak magnetic fields affect molecules and medical problems: the example of melatonin and experimental "multiple sclerosis", Med Hypotheses. 2006;66(4):811-5 [View Comments [H+]

Petersen, R.C. (1983) Bioeffects of microwaves: a review of current knowledge. Journal of Occupational and Environmental Medicine, 25, 103. [H+]

Petridou E et al, (November 1997) Electrical power lines and childhood leukemia: a study from Greece, Int J Cancer. 1997 Nov 4;73(3):345-8. [H-]

Peyman A et al, (June 2009) Evaluation Of Exposure Of School Children To Electromagnetic Fields From Wireless Computer Networks (Wi-Fi): Phase 1 Laboratory Measurements,. [H*]

Phillips JL et al, (March 2009) Electromagnetic fields and DNA damage, Pathophysiology. 2009 Mar 3. [Epub ahead of print]. [H+]

Phillips JL et al, (September 1992) Magnetic field-induced changes in specific gene transcription, Biochim Biophys Acta. 1992 Sep 24;1132(2):140-4. [H+]

Pipkin JL et al, (September 1999) Induction of stress proteins by electromagnetic fields in cultured HL-60 cells, Bioelectromagnetics. 1999 Sep;20(6):347-57. [H+]

Pokorny J et al, (May 2008) Biophysical aspects of cancer--electromagnetic mechanism, Indian J Exp Biol. 2008 May;46(5):310-21. [H*]

Pollan M et al, (March 2001) Breast cancer, occupation, and exposure to electromagnetic fields among Swedish men, Am J Ind Med. 2001 Mar;39(3):276-85. [H-]

Poole C et al, (February 1993) Depressive symptoms and headaches in relation to proximity of residence to an alternating-current transmission line right-of-way, Am J Epidemiol. 1993 Feb 1;137(3):318-30. [View on Pubmed [H+]

Poulletier de Gannes F et al, (September 2008) Amyotrophic Lateral Sclerosis (ALS) and extremely-low frequency (ELF) magnetic fields: a study in the SOD-1 transgenic mouse model, Amyotroph Lateral Scler. 2008 Sep 1:1-4. [Epub ahead of print]Cl [H-]

Pourlis AF, (March 2009) Reproductive and developmental effects of EMF in vertebrate animal models, Pathophysiology. 2009 Mar 7. [Epub ahead of print]. [H+]

Pourlis, A.F. (2009) Reproductive and developmental effects of EMF in vertebrate animal models. Pathophysiology, 16, 179-189. [W+]

Preece AW et al, (2005) Effect of 902 MHz mobile phone transmission on cognitive function in children, Bioelectromagnetics Suppl 7 S138-43. [H+]

Preece AW et al, (June 2007) Health response of two communities to military antennae in Cyprus, Occup Environ Med. 2007 Jun;64(6):402-8. [H+]

Preece, A. (2003) Mobile Phones and Cognitive Function. Electromagnetic environments and health in building, 405. [H+]

Preece, A.W., Georgiou, A.G., Dunn, E.J. & Farrow, S.C. (2007) Health response of two communities to military antennae in Cyprus. Occupational and environmental medicine, 64, 402. [H+]

Prihoda TJ, (March 2009) Genetic damage in mammalian somatic cells exposed to extremely low frequency electro-magnetic fields: A meta-analysis of data from 87 publications (1990-2007), Int J Radiat Biol. 2009 Mar;85(3):196-213 [View Comments a [W+]

Prisco MG et al, (December 2008) Effects of GSM-modulated radiofrequency electromagnetic fields on mouse bone marrow cells, Radiat Res. 2008 Dec;170(6):803-10. [W-]

Ragbetli MC et al, (July 2010) The effect of mobile phone on the number of Purkinje cells: a stereological study, Int J Radiat Biol. 2010 Jul;86(7):548-54. [H+]

Rajaei F et al, (January 2010) Effects of extremely low-frequency electromagnetic field on fertility and heights of epithelial cells in pre-implantation stage endometrium and fallopian tube in mice, Zhong Xi Yi Jie He Xue Bao. 2010 Jan;8(1):56 [W+]

Rajkovic V et al, (August 2010) Studies on the synergistic effects of extremely low-frequency magnetic fields and the endocrine-disrupting compound atrazine on the thyroid gland, Int J Radiat Biol. 2010 Aug 10. [Epub ahead of print] [View Comm [H-]

Rajkovic V et al, (July 2005) Histological characteristics of cutaneous and thyroid mast cell populations in male rats exposed to power-frequency electromagnetic fields, Int J Radiat Biol. 2005 Jul;81(7):491-9. [View o [W+]

Rajkovic V et al, (November 2005) The effect of extremely low-frequency electromagnetic fields on skin and thyroid amine- and peptide-containing cells in rats: an immunohistochemical and morphometrical study, Environ Res. 2005 Nov;99(3):369-77 [W+]

Rajkovic V et al, (September 2006) Light and electron microscopic study of the thyroid gland in rats exposed to power-frequency electromagnetic fields, J Exp Biol. 2006 Sep;209(Pt 17):3322-8. [W+]

Rao VS et al, (March 2008) Nonthermal effects of radiofrequency-field exposure on calcium dynamics in stem cell-derived neuronal cells: elucidation of calcium pathways, Radiat Res. 2008 Mar;169(3):319-29. [View on Pubm [H+]

Ravindra T et al, (December 2006) Melatonin in pathogenesis and therapy of cancer, Indian J Med Sci. 2006 Dec;60(12):523-35. [H*]

Redmayne M et al, (April 2010) Cordless telephone use: implications for mobile phone research, J Environ Monit. 2010 Apr 9;12(4):809-12. Epub 2010 Feb 2. [H*]

Reeves GI, (March 2000) Review of extensive workups of 34 patients overexposed to radiofrequency radiation, Aviat Space Environ Med. 2000 Mar;71(3):206-15. [H*]

REFLEX Report, (December 2004) Risk Evaluation of Potential Environmental Hazards From Low Frequency Electromagnetic Field Exposure Using Sensitive in vitro Methods, A project funded by the European Union under the programme "Quality of Life a [H+]

Reichmanis M et al, (1979) Relation between suicide and the electromagnetic field of overhead power lines, Physiol Chem Phys. 1979;11(5):395-403. [H+]

Reif JS et al, (August 2005) Human responses to Residential RF exposure, 2 RO1 ES0008117-04. [H+]

Reif JS et al, (February 1995) Residential exposure to magnetic fields and risk of canine lymphoma, Am J Epidemiol. 1995 Feb 15;141(4):352-9. [H+]

Reipert BM et al, (1996) Exposure to extremely low frequency magnetic fields has no effect on growth rate or clonogenic potential of multipotential haemopoietic progenitor cells, Growth Factors. 1996;13(3-4):205-17. [V [H-]

Reiser H et al, (October 1995) The influence of electromagnetic fields on human brain activity, Eur J Med Res. 1995 Oct 16;1(1):27-32. [H+]

Remondini D et al, (September 2006) Gene expression changes in human cells after exposure to mobile phone microwaves, Proteomics 2006 Sep;6(17):4745-54. [H+]

Repacholi, M. (2009) The reality of mobile phones and cancer. The New Scientist, 204, 26–27. [H+]

Reyes-Guerrero G et al, (March 2010) Extremely low-frequency electromagnetic fields differentially regulate estrogen receptor-alpha and -beta expression in the rat olfactory bulb, Neurosci Lett. 2010 Mar 3;471(2):109-13. Epub 2010 Jan 18 [View [W+]

Rezk AY et al, (February 2008) Fetal and neonatal responses following maternal exposure to mobile phones, Saudi Med J. 2008 Feb;29(2):218-23. [H+]

Ribeiroa E et al, (January 2007) Effects of subchronic exposure to radio frquency from a conventional cellular telephone on testicular function in adult rats, J Urol 177(1): 395-399. [W-]

Richter E et al, (July 2000) Cancer in radar technicians exposed to radiofrequency/microwave radiation: sentinel episodes, Int J Occup Environ Health. 2000 Jul-Sep;6(3):187-93. [H+]

Robertson JA et al, (August 2009) Low-frequency pulsed electromagnetic field exposure can alter neuroprocessing in humans, J R Soc Interface. 2009 Aug 5. [Epub ahead of print]. [H+]

Rodriguez C et al, (January 2004) Regulation of antioxidant enzymes: a significant role for melatonin, J Pineal Res. 2004 Jan;36(1):1-9. [H*]

Rodriguez C et al, (January 2004) Regulation of antioxidant enzymes: a significant role for melatonin, J Pineal Res. 2004 Jan;36(1):1-9. [H*]

Roosli M et al, (February 2004) Symptoms of ill health ascribed to electromagnetic field exposure--a questionnaire survey, Int J Hyg Environ Health. 2004 Feb;207(2):141-50. [H*]

Roosli M, (March 2008) Radiofrequency electromagnetic field exposure and non-specific symptoms of ill health: A systematic review, Environ Res. 2008 Mar 20. [H-]

Röösli, M. (2008) Radiofrequency electromagnetic field exposure and non-specific symptoms of ill health: a systematic review. Environmental research, 107, 277–287. [H+]

Rothman KJ et al, (May 1996) Overall mortality of cellular telephone customers, Epidemiology. 1996 May;7(3):303-5. [H*]

Roux D et al, (November 2007) High frequency (900 MHz) low amplitude (5 V m(-1)) electromagnetic field: a genuine environmental stimulus that affects transcription, translation, calcium and energy charge in tomato., Planta. 2007 Nov 20 [Epub a [P+]

Rubin GJ et al, (April 2006) Are some people sensitive to mobile phone signals? Within participants double blind randomised provocation study, BMJ. 2006 Apr 15;332(7546):886-91. [H-]

Rubin GJ et al, (January 2010) Idiopathic environmental intolerance attributed to electromagnetic fields (formerly 'electromagnetic hypersensitivity'): An updated systematic review of provocation studies, Bioelectromagnetics. 2010 Jan;31(1):1- [H-]

Rubin GJ et al, (March 2005) Electromagnetic hypersensitivity: a systematic review of provocation studies, Psychosom Med. 2005 Mar-Apr;67(2):224-32. [H-]

Ruediger HW, (March 2009) Genotoxic effects of radiofrequency electromagnetic fields, Pathophysiology. 2009 Mar 12. [Epub ahead of print]. [H+]

Ruiz-Gomez MJ, Martinez-Morillo M, (2009) Electromagnetic fields and the induction of DNA strand breaks, Electromagn Biol Med. 2009;28(2):201-14. [H*]

Russo P et al, (August 2010) A numerical coefficient for evaluation of the environmental impact of electromagnetic fields radiated by base stations for mobile communications, Bioelectromagnetics. 2010 Aug 5. [Epub ahead of print] [View Comment [H*]

Sadetzki S et al, (February 2008) Cellular Phone Use and Risk of Benign and Malignant Parotid Gland Tumors A Nationwide Case-Control Study, Am J Epidemiol. 2007 Dec 6 [Epub ahead of print]. [H+]

Saffer JD, Thurston SJ, (October 1995) Short exposures to 60 Hz magnetic fields do not alter MYC expression in HL60 or Daudi cells, Radiat Res. 1995 Oct;144(1):18-25. [H-]

SAGE, (April 2007) SAGE first interim assessment: Power Lines and Property, Wiring in Homes, and Electrical Equipment in Homes,. [H+]

Sainudeen Sahib. (2011) Impact of mobile phone on the density of Honey Bees. Munis Entomology & Zoology, 6, 396-399. [Es+]

Saito T et al, (2010) Power-frequency magnetic fields and childhood brain tumors: a case-control study in Japan, J Epidemiol. 2010;20(1):54-61. Epub 2009 Nov 14. [H+]

Salama N et al, (December 2009) The mobile phone decreases fructose but not citrate in rabbit semen: a longitudinal study, Syst Biol Reprod Med. 2009 Dec;55(5-6):181-7. [W+]

Salama N et al, (March 2010) Effects of exposure to a mobile phone on sexual behavior in adult male rabbit: an observational study, Int J Impot Res. 2010 Mar;22(2):127-33. [W+]

Salford L et al, (June 2003) Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones, Environ Health Perspect 2003 Jun;111(7):881-3; discussion A408. [W+]

Samkange-Zeeb F et al, (May 2004) Validation of self-reported cellular phone use, J Expo Anal Environ Epidemiol. 2004 May;14(3):245-8. [H*]

Sandstrom M et al, (February 2001) Mobile phone use and subjective symptoms. Comparison of symptoms experienced by users of analogue and digital mobile phones, Occup Med (Lond). 2001 Feb;51(1):25-35. [H+]

Sandstrom M et al, (January 1997) Neurophysiological effects of flickering light in patients with perceived electrical hypersensitivity, J Occup Environ Med. 1997 Jan;39(1):15-22. [H+]

Sannino A et al, (June 2009) Human fibroblasts and 900 MHz radiofrequency radiation: evaluation of DNA damage after exposure and co-exposure to 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5h)-furanone (MX), Radiat Res. 2009 Jun;171(6):743-51 [View [H-]

Sannino A et al, (June 2009) Induction of adaptive response in human blood lymphocytes exposed to radiofrequency radiation, Radiat Res. 2009 Jun;171(6):735-42. [H+]

Santini MT et al, (April 2009) Cellular effects of extremely low frequency (ELF) electromagnetic fields, Int J Radiat Biol. 2009 Apr;85(4):294-313. [H+]

Santini R et al, (July 2002) Investigation on the health of people living near mobile telephone relay stations: I/Incidence according to distance and sex, Pathol Biol (Paris) 2002 Jul;50(6):369-73. [H+]

Santini R et al, (September 2003) Symptoms experienced by people in vicinity of base stations: II/ Incidences of age, duration of exposure, location of subjects in relation to the antennas and other electromagnetic factors, Pathol Biol (Paris) [H+]

Saracci R, Samet J, (June 2010) Commentary: Call me on my mobile phone...or better not?--a look at the INTERPHONE study results, Int J Epidemiol. 2010 Jun;39(3):695-8. Epub 2010 May 17. [H*]

Sarimov R et al, (2004) Nonthermal GSM Microwaves Affect Chromatin Conformation in Human Lymphocytes Similar to Heat Shock, IEEE Trans Plasma Sci 2004; 32 (4): 1600 - 1608. [H+]

Saunders, R. (2005) Static magnetic fields: animal studies. Progress in Biophysics and Molecular Biology, 87, 225-239. [W+]

Saunders, T. (2002) The boiled frog syndrome: your health and the built environment. Academy Press. [H+]

Savitz DA et al, (February 1994) Prevalence of depression among electrical workers, Am J Ind Med. 1994 Feb;25(2):165-76. [H*]

Savitz DA et al, (July 1988) Case-control study of childhood cancer and exposure to 60-Hz magnetic fields, Am J Epidemiol. 1988 Jul;128(1):21-38. [H+]

Savitz DA et al, (October 2000) Case-cohort analysis of brain cancer and leukemia in electric utility workers using a refined magnetic field job-exposure matrix, Am J Ind Med. 2000 Oct;38(4):417-25. [H*]

Savitz, D.A. (2003) Health effects of electric and magnetic fields: Are we done yet? Epidemiology, 14, 15. [H+]

Scaringi M et al, (September 2007) Evaluation of the genotoxicity of the extremely low frequency-magnetic fields (ELF-MF) in workers exposed for professional reasons, G Ital Med Lav Ergon. 2007 Jul-Sep;29(3 Suppl):420-1 [View Comments and Link [H-]

Schilling CJ, (April 1997) Effects of acute exposure to ultrahigh radiofrequency radiation on three antenna engineers, Occup Environ Med. 1997 Apr;54(4):281-4. [H+]

Schoemaker MJ et al, (October 2005) Mobile phone use and risk of acoustic neuroma: results of the Interphone case-control study in five North European countries, Br J Cancer. 2005 Oct 3;93(7):842-8. [H+]

Schreier N et al, (2006) The prevalence of symptoms attributed to electromagnetic field exposure: a cross-sectional representative survey in Switzerland, Soz Praventivmed. 2006;51(4):202-9. [H*]

Schrottner J et al, (April 2007) Investigation of electric current perception thresholds of different EHS groups, Bioelectromagnetics. 2007 Apr;28(3):208-13. [H*]

Schuz J et al, (2009) Risks for central nervous system diseases among mobile phone subscribers: a Danish retrospective cohort study, PLoS ONE. 2009;4(2):e4389. Epub 2009 Feb 5. [H+]

Schuz J et al, (December 2006) Cellular telephone use and cancer risk: update of a nationwide Danish cohort, J Natl Cancer Inst. 2006 Dec 6;98(23):1707-13. [H-]

Schuz J et al, (July 2006) Radiofrequency electromagnetic fields emitted from base stations of DECT cordless phones and the risk of glioma and meningioma (Interphone Study Group, Germany), Radiat Res. 2006 Jul;166(1 Pt 1):116-9 [View Comments [H-]

Schuz J et al, (March 2001) Residential magnetic fields as a risk factor for childhood acute leukaemia: results from a German population-based case-control study, Int J Cancer. 2001 Mar 1;91(5):728-35. [H+]

Schuz J et al, (March 2006) Cellular phones, cordless phones, and the risks of glioma and meningioma (Interphone Study Group, Germany), Am J Epidemiol. 2006 Mar 15;163(6):512-20. [H*]

Schuz J, Ahlbom A, (October 2008) Exposure to electromagnetic fields and the risk of childhood leukaemia: a review, Radiat Prot Dosimetry. 2008 Oct 16. [Epub ahead of print]. [H*]

Schwarz C et al, (May 2008) Radiofrequency electromagnetic fields (UMTS, 1,950 MHz) induce genotoxic effects in vitro in human fibroblasts but not in lymphocytes, Int Arch Occup Environ Health. 2008 May;81(6):755-67. [[H+]

Seetharaman, R., Uthayakumar, G.S., Gurusamy, N. & Kumaravel, N. (2009) Mobile phone usage and cancer. pp. 627-632. [H+]

Seitz H et al, (October 2005) Electromagnetic hypersensitivity (EHS) and subjective health complaints associated with electromagnetic fields of mobile phone communication--a literature review published between 2000 and 2004, Sci Total Environ. [H-]

Seitz, H., Stinner, D., Eikmann, T., Herr, C. & Roosli, M. (2005) Electromagnetic hypersensitivity (EHS) and subjective health complaints associated with electromagnetic fields of mobile phone communication–a literature review published between 2000 and 2004. Science of the total environment, 349, 45–55. [H+]

Sekijima M et al, (March 2010) 2-GHz band CW and W-CDMA modulated radiofrequency fields have no significant effect on cell proliferation and gene expression profile in human cells, J Radiat Res (Tokyo). 2010;51(3):277-84. Epub 2010 Mar 9 [View [H-]

Severini M et al, (January 2010) Metamorphosis delay in Xenopus laevis (Daudin) tadpoles exposed to a 50 Hz weak magnetic field, Int J Radiat Biol. 2010 Jan;86(1):37-46. [W+]

Sharifian A et al, (May 2008) Effect of extremely low frequency magnetic field on antioxidant activity in plasma and red blood cells in spot welders., Int Arch Occup Environ Health. 2008 May 27. [H*]

Sharma VP et al, (October 2009) Mobile phone radiation inhibits Vigna radiata (mung bean) root growth by inducing oxidative stress, Sci Total Environ. 2009 Oct 15;407(21):5543-7. Epub 2009 Aug 13. [P+]

Sharma, V.P. & Kumar, N.R. (2010) Changes in honeybee behaviour and biology under the influence of cellphone radiations. Current Science, 98, 1376. [Es+]

Sharma, V.P., Singh, H.P., Kohli, R.K. & Batish, D.R. (2009) Mobile phone radiation inhibits Vigna radiata (mung bean) root growth by inducing oxidative stress. Science of The Total Environment, 407, 5543-5547. [P+]

Sheppard AR et al, (October 2008) Quantitative evaluations of mechanisms of radiofrequency interactions with biological molecules and processes, Health Phys. 2008 Oct;95(4):365-96. [H*]

Sievert, U., Eggert, S., Goltz, S. & Pau, H.W. (2007) Effects of Electromagnetic Fields Emitted by Cellular Phone on Auditory and Vestibular Labyrinth= Wirkung elektromagnetischer Felder des GSM-Mobilfunksystems auf auditives und vestibul\Ares Labyrinth und Hirnstamm*. Laryngo-, Rhino-, Otologie, 86, 264-270. [H+]

Simko M et al, (August 2001) Micronucleus induction in Syrian hamster embryo cells following exposure to 50 Hz magnetic fields, benzo(a)pyrene, and TPA in vitro, Mutat Res. 2001 Aug 22;495(1-2):43-50. [W+]

Simko M, Mattsson MO, (September 2004) Extremely low frequency electromagnetic fields as effectors of cellular responses in vitro: possible immune cell activation, J Cell Biochem. 2004 Sep 1;93(1):83-92. [View on Pubme [H+]

Sims S, Dent P, (2005) High-voltage Overhead Power Lines and Property Values: A Residential Study in the UK, Urban Studies, Vol. 42, No. 4, 665-694 (2005). [H+]

Singh B, Bate LA, (November 1996) Responses of pulmonary intravascular macrophages to 915-MHz microwave radiation: ultrastructural and cytochemical study, Anat Rec. 1996 Nov;246(3):343-55. [H+]

Sinha, A.K. (2008) Bio-social issues in health. Northern Book Centre. [H*]

Sirav B et al, (2009) Radio frequency radiation (RFR) from TV and radio transmitters at a pilot region in Turkey, Radiat Prot Dosimetry. 2009;136(2):114-7. Epub 2009 Aug 11. [H+]

Sirav B, Seyhan N, (2009) Blood-brain barrier disruption by continuous-wave radio frequency radiation, Electromagn Biol Med. 2009;28(2):215-22. [H+]

Soda A et al, (August 2008) Effect of exposure to an extremely low frequency-electromagnetic field on the cellular collagen with respect to signaling pathways in osteoblast-like cells, J Med Invest. 2008 Aug;55(3-4):267-78 [View Comments and L [H+]

Soderqvist F et al, (2010) Radiofrequency fields, transthyretin, and Alzheimer's disease, J Alzheimers Dis. 2010;20(2):599-606. [H+]

Soderqvist F et al, (April 2009) Mobile and cordless telephones, serum transthyretin and the blood-cerebrospinal fluid barrier: a cross-sectional study, Environ Health. 2009 Apr 21;8:19. [H+]

Soderqvist F et al, (August 2009) Exposure to an 890-MHz mobile phone-like signal and serum levels of S100B and transthyretin in volunteers, Toxicol Lett. 2009 Aug 25;189(1):63-6. Epub 2009 May 7. [H+]

Soeyonggo, T. & Wang, S. (2010) Cell Phones and Cancer: A Short Communication. University of Toronto Medical Journal, 87, 125. [H+]

Sokolovic D et al, (September 2008) Melatonin Reduces Oxidative Stress Induced by Chronic Exposure of Microwave Radiation from Mobile Phones in Rat Brain, J Radiat Res (Tokyo). 2008 Sep 29. [Epub ahead of print]. [View [W+]

Sommer AM et al, (January 2009) Effects of Radiofrequency Electromagnetic Fields (UMTS) on Reproduction and Development of Mice: A Multi-generation Study, Radiat Res. 2009 Jan;171(1):89-95. [W-]

Stam R, (October 2010) Electromagnetic fields and the blood-brain barrier, Brain Res Rev. 2010 Oct 5;65(1):80-97. Epub 2010 Jun 13 [H*]

Stang A et al, (January 2001) The possible role of radiofrequency radiation in the development of uveal melanoma, Epidemiology. 2001 Jan;12(1):7-12. [H+]

Stang A et al, (January 2009) Mobile phone use and risk of uveal melanoma: results of the risk factors for uveal melanoma case-control study, J Natl Cancer Inst. 2009 Jan 21;101(2):120-3. Epub 2009 Jan 13. [View on Pub [H-]

Stenberg B et al, (October 2002) Medical and social prognosis for patients with perceived hypersensitivity to electricity and skin symptoms related to the use of visual display terminals, Scand J Work Environ Health. 2002 Oct;28(5):349-57 [Vie [H+]

Stovner LJ et al, (2008) Nocebo as headache trigger: evidence from a sham-controlled provocation study with RF fields, Acta Neurol Scand Suppl. 2008;188:67-71. [H-]

St-Pierre LS et al, (April 2008) Altered blood chemistry and hippocampal histomorphology in adult rats following prenatal exposure to physiologically-patterned, weak (50-500 nanoTesla range) magnetic fields, Int J Radiat Biol. 2008 Apr;84(4):3 [W+]

Strayer D et al, (March 2003) Cell phone-induced failures of visual attention during simulated driving, J Exp Psychol Appl Mar;9(1):23-32 [H*]

Summers-Smith, J.D. (2003) The decline of the House Sparrow: a review. British Birds, 96, 439–446. [B+]

Sun W et al, (October 2010) Effects of 50-Hz magnetic field exposure on hormone secretion and apoptosis-related gene expression in human first trimester villous trophoblasts in vitro, Bioelectromagnetics. 2010 Oct;31(7):566-72 [View Comments a [H+]

Swanson J et al, (September 2006) Power-frequency electric and magnetic fields in the light of Draper *et al.* 2005, Ann N Y Acad Sci. 2006 Sep;1076:318-30. [H*]

Szmigielski S et al, (1998) Alteration of diurnal rhythms of blood pressure and heart rate to workers exposed to radiofrequency electromagnetic fields, Blood Press Monit. 1998;3(6):323-30. [H+]

Szmigielski S, (February 1996) Cancer morbidity in subjects occupationally exposed to high frequency (radiofrequency and microwave) electromagnetic radiation, Sci Total Environ. 1996 Feb 2;180(1):9-17. [H+]

Szmigielski. (2007) Influnce of radar radiation on Breeding biology of Tits (Parus sp.). Electromagnetic biology and Medicine, 26, 235-238. [B+]

Szyjkowska A et al, (October 2005) Subjective symptoms related to mobile phone use--a pilot study, Pol Merkur Lekarski. 2005 Oct;19(112):529-32. [H*]

Takahashi S et al, (March 2010) Lack of adverse effects of whole-body exposure to a mobile telecommunication electromagnetic field on the rat fetus, Radiat Res. 2010 Mar;173(3):362-72. [W-]

Takebayashi T et al, (December 2006) Mobile phone use and acoustic neuroma risk in Japan, Occup Environ Med. 2006 Dec;63(12):802-7. [H-]

Takebayashi T et al, (February 2008) Mobile phone use, exposure to radiofrequency electromagnetic field, and brain tumour: a case-control study, Br J Cancer. 2008 Feb 12;98(3):652-9. [H-]

Takebayashi, T., Varsier, N., Kikuchi, Y., Wake, K., Taki, M., Watanabe, S., Akiba, S. & Yamaguchi, N. (2008) Mobile phone use, exposure to radiofrequency electromagnetic field, and brain tumour: a case-control study. British journal of cancer, 98, 652-659. [H*]

Tamarkin L et al, (May 1982) Decreased nocturnal plasma melatonin peak in patients with estrogen receptor positive breast cancer, Science. 1982 May 28;216(4549):1003-5. [H*]

Tamarkin L et al, (November 1981) Melatonin inhibition and pinealectomy enhancement of 7,12-dimethylbenz(a)anthracene-induced mammary tumors in the rat, Cancer Res. 1981 Nov;41(11 Pt 1):4432-6. [W*]

Tanner, J.A., Romero-Sierra, C. & Davie, S.J. (1967) Non-thermal effects of microwave radiation on birds. Nature, 216, 1139. [B+]

Tanwar, V.S. (2006a) Living dangerously in Indian cities: An RF radiation pollution perspective. Proceedings of the 9th INCEMIC, p. 458–466. Bangalore. [H+]

Tattersall JE et al, (June 2001) Effects of low intensity radiofrequency electromagnetic fields on electrical activity in rat hippocampal slices, Brain Res. 2001 Jun 15;904(1):43-53. [W+]

Tekriwal, S.K. & Choudhary, M. (2010) Electro magnetic radiation: Legislative and Judicial intent. pp. 451-457. [H*]

Theriault G, Li CY, (September 1997) Risks of leukaemia among residents close to high voltage transmission electric lines, Occup Environ Med. 1997 Sep;54(9):625-8. [H+]

Thomas S et al, (February 2010) Exposure to radio-frequency electromagnetic fields and behavioural problems in Bavarian children and adolescents, Eur J Epidemiol. 2010 Feb;25(2):135-41. Epub 2009 Dec 4. [View on Pubmed [H+]

Thun-Battersby S et al, (August 1999) Exposure of Sprague-Dawley rats to a 50-Hertz, 100-microTesla magnetic field for 27 weeks facilitates mammary tumorigenesis in the 7,12-dimethylbenz[a]-anthracene model of breast cancer, Cancer Res. 1999 A [W+]

Thuroczy G et al, (2008) Exposure to 50 Hz magnetic field in apartment buildings with built-in transformer stations in Hungary, Radiat Prot Dosimetry. 2008;131(4):469-73. Epub 2008 Jul 30. [H*]

Tikhonova GI et al, (September 2003) Remote effects of occupational and non-occupational exposure to electromagnetic fields of power-line frequency. Epidemiological studies, Radiats Biol Radioecol. 2003 Sep-Oct;43(5):555-8 [View Comments and L [H*]

Tkalec M et al, (November 2008) Effects of radiofrequency electromagnetic fields on seed germination and root meristematic cells of Allium cepa L, Mutat Res. 2008 Nov 5. [Epub ahead of print]. [P+]

Tomenius L, (1986) 50-Hz electromagnetic environment and the incidence of childhood tumors in Stockholm County, Bioelectromagnetics. 1986;7(2):191-207. [H+]

Tomitsch J et al, (April 2010) Survey of electromagnetic field exposure in bedrooms of residences in lower Austria, Bioelectromagnetics. 2010 Apr;31(3):200-8. [H*]

Tonini R et al, (November 2001) Calcium protects differentiating neuroblastoma cells during 50 Hz electromagnetic radiation, Biophys J. 2001 Nov;81(5):2580-9. [H+]

Touitou Y et al, (June 2003) Magnetic fields and the melatonin hypothesis: a study of workers chronically exposed to 50-Hz magnetic fields, Am J Physiol Regul Integr Comp Physiol. 2003 Jun;284(6):R1529-35. [View on Pub [H-]

Tuinstra R et al, (1998) Protein kinase C activity following exposure to magnetic field and phorbol ester, Bioelectromagnetics. 1998;19(8):469-76. [H+]

Tynes T et al, (March 1996) Incidence of breast cancer in Norwegian female radio and telegraph operators, Cancer Causes Control. 1996 Mar;7(2):197-204. [H+]

Tynes T et al, (May 2003) Residential and occupational exposure to 50 Hz magnetic fields and malignant melanoma: a population based study, Occup Environ Med. 2003 May;60(5):343-7. [H+]

Tynes T, Haldorsen T, (February 1997) Electromagnetic fields and cancer in children residing near Norwegian high-voltage power lines, Am J Epidemiol. 1997 Feb 1;145(3):219-26. [H-]

Tynes T, Haldorsen T, (October 2003) Residential and occupational exposure to 50 Hz magnetic fields and hematological cancers in Norway, Cancer Causes Control. 2003 Oct;14(8):715-20. [H*]

Ubeda A et al, (1994) Chick embryo development can be irreversibly altered by early exposure to weak extremely-low-frequency magnetic fields, Bioelectromagnetics. 1994;15(5):385-98. [B+]

Uckun FM et al, (November 1995) Exposure of B-lineage lymphoid cells to low energy electromagnetic fields stimulates Lyn kinase, J Biol Chem. 1995 Nov 17;270(46):27666-70. [H+]

UKCCS, (December 1999) Exposure to power-frequency magnetic fields and the risk of childhood cancer. UK Childhood Cancer Study Investigators, Lancet. 1999 Dec 4;354(9194):1925-31. [H-]

Valberg PA et al, (July 1997) Can low-level 50/60 Hz electric and magnetic fields cause biological effects?, Radiat Res. 1997 Jul;148(1):2-21. [H*]

Valberg, P.A., Kavet, R. & Rafferty, C.N. (1997) Can low-level 50/60 Hz electric and magnetic fields cause biological effects? Radiation Research, 148, 2–21. [H+]

Valbonesi P et al, (March 2008) Evaluation of HSP70 Expression and DNA Damage in Cells of a Human Trophoblast Cell Line Exposed to 1.8 GHz Amplitude-Modulated Radiofrequency Fields, Radiat Res. 2008 Mar;169(3):270-9. [[H-]

van Kleef E et al, (June 2010) Risk and benefit perceptions of mobile phone and base station technology in Bangladesh, Risk Anal. 2010 Jun;30(6):1002-15. Epub 2010 Apr 8. [H*]

van Rongen E et al, (October 2009) Effects of radiofrequency electromagnetic fields on the human nervous system, J Toxicol Environ Health B Crit Rev. 2009 Oct;12(8):572-97. [H-]

van Wijngaarden E et al, (April 2000) Exposure to electromagnetic fields and suicide among electric utility workers: a nested case-control study, Occup Environ Med. 2000 Apr;57(4):258-63. [H+]

van Wijngaarden E et al, (July 2001) Population-based case-control study of occupational exposure to electromagnetic fields and breast cancer, Ann Epidemiol. 2001 Jul;11(5):297-303. [H+]

van Wijngaarden E, (January 2003) An exploratory investigation of suicide and occupational exposure, J Occup Environ Med. 2003 Jan;45(1):96-101. [H+]

van Zwieten MJ et al, (September 1984) Differences in DMBA-induced mammary neoplastic responses in two lines of Sprague-Dawley rats, Eur J Cancer Clin Oncol. 1984 Sep;20(9):1199-204. [W*]

Vanderstraeten J, Verschaeve L, (September 2008) Gene and protein expression following exposure to radiofrequency fields from mobile phones, Environ Health Perspect. 2008 Sep;116(9):1131-5. [H*]

vanEngelsdorp, D., Hayes Jr, J., Underwood, R.M. & Pettis, J.S. (2010) A survey of honey bee colony losses in the United States, fall 2008 to spring 2009. [Es+]

VanZant, K. Does the cost of our technology become too high? Gorillas at risk from cellphones. [W+]

Velizarov S et al, (February 1999) The effects of radiofrequency fields on cell proliferation are non-thermal, Bioelectrochem Bioenerg. 1999 Feb;48(1):177-80. [H+]

Verkasalo PK et al, (December 1997) Magnetic fields of transmission lines and depression, Am J Epidemiol. 1997 Dec 15;146(12):1037-45. [H+]

Verkasalo PK et al, (October 1993) Risk of cancer in Finnish children living close to power lines, BMJ. 1993 Oct 9;307(6909):895-9. [H*]

Verloock L et al, (April 2010) Procedure for assessment of general public exposure from WLAN in offices and in wireless sensor network testbed, Health Phys. 2010 Apr;98(4):628-38. [H*]

Verschaeve L, (November 2008) Genetic damage in subjects exposed to radiofrequency radiation, Mutat Res. 2008 Nov 27. [Epub ahead of print]. [H+]

Vianale G et al, (April 2008) Extremely low frequency electromagnetic field enhances human keratinocyte cell growth and decreases proinflammatory chemokine production, Br J Dermatol. 2008 Apr 10 [Epub ahead of print]. [H+]

Viel JF et al, (August 2009) Radiofrequency exposure in the French general population: band, time, location and activity variability, Environ Int. 2009 Nov;35(8):1150-4. Epub 2009 Aug 4. [H+]

Viel JF et al, (March 2009) Residential exposure to radiofrequency fields from mobile-phone base stations, and broadcast transmitters: a population-based survey with personal meter, Occup Environ Med. 2009 Mar 30. [Epub ahead of print] [View C [H*]

Vijayalaxmi , Obe G, (July 2005) Controversial cytogenetic observations in mammalian somatic cells exposed to extremely low frequency electromagnetic radiation: a review and future research recommendations, Bioelectromagnetics. 2005 Jul;26(5): [W*]

Vijayalaxmi , Prihoda TJ, (May 2008) Genetic damage in mammalian somatic cells exposed to radiofrequency radiation: a meta-analysis of data from 63 publications (1990-2005), Radiat Res. 2008 May;169(5):561-74. [View on [W*]

Villeneuve PJ et al, (February 2002) Brain cancer and occupational exposure to magnetic fields among men: results from a Canadian population-based case-control study, Int J Epidemiol. 2002 Feb;31(1):210-7. [View on Pub [H+]

Vorobyov V et al, (May 2010) Repeated exposure to low-level extremely low frequency-modulated microwaves affects cortex-hypothalamus interplay in freely moving rats: EEG study, Int J Radiat Biol. 2010 May;86(5):376-83. [W+]

Vrijheid M et al, (April 2006) Validation of short term recall of mobile phone use for the Interphone study, Occup Environ Med. 2006 Apr;63(4):237-43. [H*]

Vrijheid M et al, (May 2008) Recall bias in the assessment of exposure to mobile phones, J Expo Sci Environ Epidemiol. 2008 May 21. [H-]

Vrijheid M et al, (May 2009) Determinants of mobile phone output power in a multinational study - implications for exposure assessment, Occup Environ Med. 2009 May 21. [Epub ahead of print]. [H*]

Wake K et al, (October 2009) The estimation of 3D SAR distributions in the human head from mobile phone compliance testing data for epidemiological studies, Phys Med Biol. 2009 Oct 7;54(19):5695-706. Epub 2009 Sep 1. [[H*]

Wakeford R, (August 2004) The cancer epidemiology of radiation, Oncogene. 2004 Aug 23;23(38):6404-28. [H*]

Wallace D et al, (January 2010) Do TETRA (Airwave) Base Station Signals Have a Short-Term Impact on Health and Well-Being? A Randomized Double-Blind Provocation Study, Environ Health Perspect. 2010 Jan 14. [Epub ahead of print] [View Comments [H-]

Walleczek J, (October 1992) Electromagnetic field effects on cells of the immune system: the role of calcium signaling, FASEB J. 1992 Oct;6(13):3177-85. [H+]

Wang B, Lai H, (January 2000) Acute exposure to pulsed 2450-MHz microwaves affects water-maze performance of rats, Bioelectromagnetics. 2000 Jan;21(1):52-6. [W+]

Wang Q et al, (July 2004) Effect of 900MHz electromagnetic fields on energy metabolism of cerebral cortical neurons in postnatal rat, Wei Sheng Yan Jiu. 2004 Jul;33(4):428-9, 432. [W+]

Wang Q et al, (July 2004) Effect of 900MHz electromagnetic fields on energy metabolism of cerebral cortical neurons in postnatal rat, Wei Sheng Yan Jiu. 2004 Jul;33(4):428-9, 432. [W+]

Wang Q et al, (March 2005) Effect of 900Mhz electromagnetic fields on energy metabolism in postnatal rat cerebral cortical neurons, Wei Sheng Yan Jiu. 2005 Mar;34(2):155-8. [W+]

Wang Q et al, (September 2005) Effect of 900 MHz electromagnetic fields on the expression of GABA receptor of cerebral cortical neurons in postnatal rats, Wei Sheng Yan Jiu. 2005 Sep;34(5):546-8. [W+]

Wang Q et al, (September 2005) Effect of 900 MHz electromagnetic fields on the expression of GABA receptor of cerebral cortical neurons in postnatal rats, Wei Sheng Yan Jiu. 2005 Sep;34(5):546-8. [W+]

Warnke, U. (2007) Bees, birds and mankind. [B+]

Warren HG et al, (April 2003) Cellular telephone use and risk of intratemporal facial nerve tumor, Laryngoscope. 2003 Apr;113(4):663-7. [H-]

Wartenberg D, (2001) Residential EMF exposure and childhood leukemia: meta-analysis and population attributable risk, Bioelectromagnetics. 2001;Suppl 5:S86-104. [H+]

Wasserman, F.E., Dowd, C., Schlinger, B.A., Byman, D., Battista, S.P. & Kunz, T.H. (1984) The effects of microwave radiation on avian dominance behavior. Bioelectromagnetics, 5, 331-339. [B+]

Wei M et al, (February 2000) Exposure to 60-Hz magnetic fields and proliferation of human astrocytoma cells in vitro, Toxicol Appl Pharmacol. 2000 Feb 1;162(3):166-76. [H+]

Wertheimer N et al, (1995) Childhood cancer in relation to indicators of magnetic fields from ground current sources, Bioelectromagnetics. 1995;16(2):86-96. [H+]

Wertheimer N, Leeper E, (March 1979) Electrical wiring configurations and childhood cancer, Am J Epidemiol. 1979 Mar;109(3):273-84. [H+]

Westerman R, Hocking B, (May 2004) Diseases of modern living: neurological changes associated with mobile phones and radiofrequency radiation in humans, Neurosci Lett. 2004 May 6;361(1-3):13-6. [H+]

Wey HE et al, (February 2000) 50-Hertz magnetic field and calcium transients in Jurkat cells: results of a research and public information dissemination (RAPID) program study, Environ Health Perspect. 2000 Feb;108(2):135-40 [View Comments and [H-]

Weyandt TB et al, (November 1996) Semen analysis of military personnel associated with military duty assignments, Reprod Toxicol. 1996 Nov-Dec;10(6):521-8 [View Comments and [H+]

WHO. (2010) WHO | What is the International EMF Project?, http://www.who.int/peh-emf/project/EMF_Project/en/index1.html [H*]

Wiart J et al, (July 2008) Analysis of RF exposure in the head tissues of children and adults, Phys Med Biol. 2008 Jul 7;53(13):3681-95. [H*]

Wiholm C et al, (September 2008) Mobile phone exposure and spatial memory, Bioelectromagnetics. 2008 Sep 15. [Epub ahead of print]. [H+]

Wijngaarden, E. van, Savitz, D.A., Kleckner, R.C., Cai, J. & Loomis, D. (2000) Exposure to Electromagnetic Fields and Suicide among Electric Utility Workers: A Nested Case-Control Study. Occupational and Environmental Medicine, 57, 258-263. [H+]

Wilen J et al, (April 2003) Subjective symptoms among mobile phone users--a consequence of absorption of radiofrequency fields?, Bioelectromagnetics. 2003 Apr;24(3):152-9. [H+]

Wilen J et al, (April 2006) Psychophysiological tests and provocation of subjects with mobile phone related symptoms, Bioelectromagnetics 2006 Apr;27(3):204-14. [H-]

Wilson BW, (1988) Chronic exposure to ELF fields may induce depression, Bioelectromagnetics. 1988;9(2):195-205. [H+]

Winker R et al, (August 2005) Chromosomal damage in human diploid fibroblasts by intermittent exposure to extremely low-frequency electromagnetic fields, Mutat Res. 2005 Aug 1;585(1-2):43-9. [H+]

Wolf R, Wolf D, (April 2004) Increased incidence of cancer near a cell-phone transmitter station, International Journal of Cancer Prevention, 1(2) April 2004. [H+]

Woods M et al, (November 2000) Lyn and syk tyrosine kinases are not activated in B-lineage lymphoid cells exposed to low-energy electromagnetic fields, FASEB J. 2000 Nov;14(14):2284-90. [H-]

Xu S et al, (October 2009) Exposure to 1800 MHz radiofrequency radiation induces oxidative damage to mitochondrial DNA in primary cultured neurons, Brain Res. 2010 Jan 22;1311:189-96. Epub 2009 Oct 30. [H+]

Yakymenko I, Sidorik E, (July 2010) Risks of carcinogenesis from electromagnetic radiation of mobile telephony devices, Exp Oncol. 2010 Jul;32(2):54-60. [H+]

Yan JG et al, (2008) Upregulation of specific mRNA levels in rat brain after cell phone exposure, Electromagn Biol Med. 2008;27(2):147-54. [W+]

Yan JG et al, (October 2007) Effects of cellular phone emissions on sperm motility in rats, Fertil Steril. 2007 Oct;88(4):957-64. Epub 2007 Jul 12. [W+]

Yang Y et al, (December 2008) Case-only study of interactions between DNA repair genes (hMLH1, APEX1, MGMT, XRCC1 and XPD) and low-frequency electromagnetic fields in childhood acute leukemia, Leuk Lymphoma. 2008 Dec;49(12):2344-50 [View Comme [H+]

Yang Y et al, (December 2008) Case-only study of interactions between DNA repair genes (hMLH1, APEX1, MGMT, XRCC1 and XPD) and low-frequency electromagnetic fields in childhood acute leukemia, Leuk Lymphoma. 2008 Dec;49(12):2344-50 [View Comme [H+]

Yao K et al, (May 2008) Effect of superposed electromagnetic noise on DNA damage of lens epithelial cells induced by microwave radiation, Invest Ophthalmol Vis Sci. 2008 May;49(5):2009-15. [H+]

Yao K et al, (May 2008) Electromagnetic noise inhibits radiofrequency radiation-induced DNA damage and reactive oxygen species increase in human lens epithelial cells, Mol Vis. 2008 May 19;14:964-9. [H+]

Yeolekar, M.E. & Sharma, A. (2004) Use of Mobile Phones in ICU-Why Not Ban? JOURNAL-ASSOCIATION OF PHYSICIANS OF INDIA, 52, 311-313. [H+]

Yildirim MS et al, (2010) Effect of mobile phone station on micronucleus frequency and chromosomal aberrations in human blood cells, Genet Couns. 2010;21(2):243-51. [H-]

Yokus B et al, (October 2008) Extremely low frequency magnetic fields cause oxidative DNA damage in rats, Int J Radiat Biol. 2008 Oct;84(10):789-95. [W+]

Yurekli A et al, (2006) GSM base station electromagnetic radiation and oxidative stress in rats, Electromagn Biol Med 25(3):177-88. [W+]

Zach, R. & Mayoh, K.R. (1982) Breeding Biology of Trees Swallows and House Wrens in a Gradient of Gamma Radiation. Ecology, 1720–1728. [B+]

Zach, R. & Mayoh, K.R. (1984b) Gamma Radiation Effects on Nestling Tree Swallows. Ecology, 65, 1641-1647. [B+]

Zach, R. & Mayoh, K.R. (1986) Gamma-radiation effects on nestling House Wrens: a field study. Radiation research, 105, 49–57. [B-]

Zach, R., Hawkins, J.L. & Sheppard, S.C. (1993) Effects of ionizing radiation on breeding swallows at current radiation protection standards. Environmental toxicology and chemistry, 12, 779–786. [B-]

Zareen N et al, (March 2009) Derangement of chick embryo retinal differentiation caused by radiofrequency electromagnetic fields, Congenit Anom (Kyoto). 2009 Mar;49(1):15-9. [B+]

Zecca L et al, (1998) Biological effects of prolonged exposure to ELF electromagnetic fields in rats: III. 50 Hz electromagnetic fields, Bioelectromagnetics. 1998;19(1):57-66. [W+]

Zhang SZ et al, (August 2008) Effect of 1.8 GHz radiofrequency electromagnetic fields on gene expression of rat neurons, Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 2008 Aug;26(8):449-52. [W+]

Zhao Z et al, (July 1994) The effects of radiofrequency (< 30 MHz) radiation in humans, Rev Environ Health. 1994 Jul-Dec;10(3-4):213-5. [H-]

Zhijian C et al, (January 2010) Impact of 1.8-GHz radiofrequency radiation (RFR) on DNA damage and repair induced by doxorubicin in human B-cell lymphoblastoid cells, Mutat Res. 2010 Jan;695(1-2):16-21. Epub 2009 Oct 13 [View Comments and Link [H+]

Zhou, S.A. & Uesaka, M. (2006) Bioelectrodynamics in living organisms. International Journal of Engineering Science, 44, 67-92. [H*]

Cell Towers; Epidemiological evidence for a health risk from mobile phone base stations, Int J Occup Environ Health. (Hardell et al); 2010

Display Settings:
Abstract
Send to:

Int J Occup Environ Health. 2010 Jul-Sep;16(3):263-7.

Epidemiological evidence for a health risk from mobile phone base stations.

Khurana VG, Hardell L, Everaert J, Bortkiewicz A, Carlberg M, Ahonen M.
Source
Department of Neurosurgery, The Canberra Hospital, The Australian National University Medical School, Garran, Australia vgkhurana@gmail.com

Abstract
Human populations are increasingly exposed to microwave/radiofrequency (RF) emissions from wireless communication technology, including mobile phones and their base stations. By searching PubMed, we identified a total of 10 epidemiological studies that assessed for putative health effects of mobile phone base stations. Seven of these studies explored the association between base station proximity and neurobehavioral effects and three investigated cancer. We found that eight of the 10 studies reported increased prevalence of adverse neurobehavioral symptoms or cancer in populations living at distances < 500 meters from base stations. None of the studies reported exposure above accepted international guidelines, suggesting that current guidelines may be inadequate in protecting the health of human populations. We believe that comprehensive epidemiological studies of long-term mobile phone base station exposure are urgently required to more definitively understand its health impact.

PMID:
20662418
[PubMed - indexed for MEDLINE]

MeSH Terms
MeSH Terms
Cellular Phone*
Electromagnetic Fields/adverse effects*
Environmental Exposure/adverse effects*
Epidemiologic Studies
Humans
Radio Waves/adverse effects*
Risk Assessment

Cell Towers; Biological effects from exposure to electromagnetic radiation emitted by cell tower base stations and other antenna arrays
B. Blake Levitt and Henry Lai, Environ. Rev., 2010

Biological effects from exposure to electromagnetic radiation emitted by cell tower base stations and other antenna arrays

B. Blake Levitt and Henry Lai

Abstract: The siting of cellular phone base stations and other cellular infrastructure such as roof-mounted antenna arrays, especially in residential neighborhoods, is a contentious subject in land-use regulation. Local resistance from nearby residents and landowners is often based on fears of adverse health effects despite reassurances from telecommunications service providers that international exposure standards will be followed. Both anecdotal reports and some epidemiology studies have found headaches, skin rashes, sleep disturbances, depression, decreased libido, increased rates of suicide, concentration problems, dizziness, memory changes, increased risk of cancer, tremors, and other neurophysiological effects in populations near base stations. The objective of this paper is to review the existing studies of people living or working near cellular infrastructure and other pertinent studies that could apply to long-term, low-level radiofrequency radiation (RFR) exposures. While specific epidemiological research in this area is sparse and contradictory, and such exposures are difficult to quantify given the increasing background levels of RFR from myriad personal consumer products, some research does exist to warrant caution in infrastructure siting. Further epidemiology research that takes total ambient RFR exposures into consideration is warranted. Symptoms reported today may be classic microwave sickness, first described in 1978. Nonionizing electromagnetic fields are among the fastest growing forms of environmental pollution. Some extrapolations can be made from research other than epidemiology regarding biological effects from exposures at levels far below current exposure guidelines.

Key words: radiofrequency radiation (RFR), antenna arrays, cellular phone base stations, microwave sickness, nonionizing electromagnetic fields, environmental pollution.

Résumé : La localisation des stations de base pour téléphones cellulaires et autres infrastructures cellulaires, comme les installations d'antennes sur les toitures, surtout dans les quartiers résidentiels, constitue un sujet litigieux d'utilisation du territoire. La résistance locale de la part des résidents et propriétaires fonciers limitrophes repose souvent sur les craintes d'effets adverses pour la santé, en dépit des réassurances venant des fournisseurs de services de télécommunication, à l'effet qu'ils appliquent les standards internationaux d'exposition. En plus de rapports anecdotiques, certaines études épidémiologiques font état de maux de tête, d'éruption cutanée, de perturbation du sommeil, de dépression, de diminution de libido, d'augmentations du taux de suicide, de problèmes de concentration, de vertiges, d'altération de la mémoire, d'augmentation du risque de cancers, de trémulations et autres effets neurophysiologiques, dans les populations vivant au voisinage des stations de base. Les auteurs révisent ici les études existantes portant sur les gens, vivant ou travaillant près d'infrastructures cellulaires ou autres études pertinentes qui pourraient s'appliquer aux expositions à long terme à la radiation de radiofréquence de faible intensité « RFR ». Bien que la recherche épidémiologique spécifique dans ce domaine soit rare et contradictoire, et que de telles expositions soient difficiles à quantifier compte tenu des degrés croissants du bruit de fond des RFR provenant de produits de myriades de consommateurs personnels, il existe certaines recherches qui justifient la prudence dans l'installation des infrastructures. Les futures études épidémiologiques sont nécessaires afin de prendre en compte la totalité des expositions à la RFR ambiante. Les symptômes rapportés jusqu'ici pourraient correspondre à la maladie classique des micro-ondes, décrite pour la première fois en 1978. Les champs électromagnétiques non-ionisants constituent les formes de pollution environnementale croissant le plus rapidement. On peut effectuer certaines extrapolations à partir de recherches autres qu'épidémiologiques concernant les effets biologiques d'expositions à des degrés bien au-dessous des directives internationales.

Mots-clés : radiofréquence de faible intensité « RFR », les installations d'antennes, des stations de base pour téléphones cellulaires, la maladie classique des micro-ondes, les champs électromagnétiques non-ionisants, pollution environnementale.

[Traduit par la Rédaction]

Received 30 April 2010. Accepted 6 August 2010. Published on the NRC Research Press Web site at er.nrc.ca on 5 November 2010.

B.B. Levitt.[1] P.O. Box 2014, New Preston, CT 06777, USA.
H. Lai. Department of Bioengineering, Box 355061, University of Washington, Seattle, WA 98195, USA.

[1]Corresponding author (e-mail: blakelevit@cs.com; bbl353355@gmail.com).

JA 06262

1. Introduction

Wireless technologies are ubiquitous today. According to the European Information Technology Observatory, an industry-funded organization in Germany, the threshold of 5.1 billion cell phone users worldwide will be reached by the end of 2010 — up from 3.3 billion in 2007. That number is expected to increase by another 10% to 5.6 billion in 2011, out of a total worldwide population of 6.5 billion.[2] In 2010, cell phone subscribers in the U.S. numbered 287 million, Russia 220 million, Germany 111 million, Italy 87 million, Great Britain 81 million, France 62 million, and Spain 57 million. Growth is strong throughout Asia and in South America but especially so in developing countries where landline systems were never fully established.

The investment firm Bank of America Merril-Lynch estimated that the worldwide penetration of mobile phone customers is twice that of landline customers today and that America has the highest minutes of use per month per user.[3] Today, 94% of Americans live in counties with four or more wireless service providers, plus 99% of Americans live in counties where next generation, 3G (third generation), 4G (fourth generation), and broadband services are available. All of this capacity requires an extensive infrastructure that the industry continues to build in the U.S., despite a 93% wireless penetration of the total U.S. population.[4]

Next generation services are continuing to drive the build-out of both new infrastructure as well as adaptation of pre-existing sites. According to the industry, there are an estimated 251 618 cell sites in the U.S. today, up from 19 844 in 1995.[4] There is no comprehensive data for antennas hidden inside of buildings but one industry-maintained Web site (www.antennasearch.com), allows people to type in an address and all antennas within a 3 mile (1 mile = 1.6 km) area will come up. There are hundreds of thousands in the U.S. alone.

People are increasingly abandoning landline systems in favor of wireless communications. One estimate in 2006 found that 42% of all wireless subscribers used their wireless phone as their primary phone. According to the National Center for Health Statistics of the U.S. Centers for Disease Control (CDC), by the second half of 2008, one in every five American households had no landlines but did have at least one wireless phone (Department of Health and Human Services 2008). The figures reflected a 2.7% increase over the first half of 2008 — the largest jump since the CDC began tracking such data in 2003, and represented a total of 20.2% of the U.S. population — a figure that coincides with industry estimates of 24.50% of completely wireless households in 2010.[5] The CDC also found that approximately 18.7% of all children, nearly 14 million, lived in households with only wireless phones. The CDC further found that one in every seven American homes, 14.5% of the population, received all or almost all of their calls via wireless phones, even when there was a landline in the home. They called these “wireless-mostly households.”

The trend away from landline phones is obviously increasing as wireless providers market their services specifically toward a mobile customer, particularly younger adults who readily embrace new technologies. One study (Silke et al. 2010) in Germany found that children from lower socioeconomic backgrounds not only owned more cell phones than children from higher economic groups, but also used their cell phones more often — as determined by the test groups’ wearing of personal dosimetry devices. This was the first study to track such data and it found an interesting contradiction to the assumption that higher socioeconomic groups were the largest users of cell services. At one time, cell phones were the status symbol of the wealthy. Today, it is also a status symbol of lower socioeconomic groups. The CDC found in their survey discussed above that 65.3% of adults living in poverty or living near poverty were more likely than higher income adults to be living in households with wireless only telephones. There may be multiple reasons for these findings, including a shift away from cell phone dialogues to texting in younger adults in higher socioeconomic categories.

In some developing countries where landline systems have never been fully developed outside of urban centers, cell phones are the only means of communication. Cellular technology, especially the new 3G, 4G, and broadband services that allow wireless communications for real-time voice communication, text messaging, photos, Internet connections, music and video downloads, and TV viewing, is the fastest growing segment of many economies that are in otherwise sharp decline due to the global economic downturn.

There is some indication that although the cellular phone markets for many European countries are more mature than in the U.S., people there may be maintaining their landline use while augmenting with mobile phone capability. This may be a consequence of the more robust media coverage regarding health and safety issues of wireless technology in the European press, particularly in the UK, as well as recommendations by European governments like France and Germany[6] that citizens not abandon their landline phones or wired computer systems because of safety concerns. According to OfCom’s 2008 *Communications Market Interim Report* (OfCom 2008), which provided information up to December 2007, approximately 86% of UK adults use cell phones. While four out of five households have both cell phones and landlines, only 11% use cell phones exclusively, a total down from 28% noted by this group in 2005. In addition, 44% of UK adults use text messaging on a daily basis. Fixed landline services fell by 9% in 2007 but OfCom notes that landline services continue to be strong despite the fact that mobile services also continued to grow by 16%. This indicates that people are continuing to use both landlines and wireless technology rather than choosing one over the other in the UK. There were 51 300 UK base station sites in

[2] http://www.eito.com/pressinformation_20100811.htm. (Accessed October 2010.)
[3] http://www.ctia.org/advocacy/research/index.cfm/AID/10377. (Accessed October 2010.)
[4] http://www.ctia.org/advocacy/research/index.cfm/AID/10323. (Accessed October 2010.)
[5] http://www.ctia.org/advocacy/research/index.cfm/AID/10323. (Accessed October 2010.)
[6] http://www.icems.eu/docs/deutscher_bundestag.pdf and http://www.icems.eu/docs/resolutions/EP_EMF_resolution_2APR09.pdf. (Accessed October 2010.)

the beginning of 2009 (two-thirds installed on existing buildings or structures) with an estimated 52 900 needed to accommodate new 3G and 4G services by the end of 2009.

Clearly, this is an enormous global industry. Yet, no money has ever been appropriated by the industry in the U.S., or by any U.S. government agency, to study the potential health effects on people living near the infrastructure. The most recent research has all come from outside of the U.S. According to the CTIA – The Wireless Association, ''If the wireless telecom industry were a country, its economy would be bigger than that of Egypt, and, if measured by GNP (gross national product), [it] would rank as the 46th largest country in the world.'' They further say, ''It took more than 21 years for color televisions to reach 100 million consumers, more than 90 years for landline service to reach 100 million consumers, and less than 17 years for wireless to reach 100 million consumers.''[7]

In lieu of building new cell towers, some municipalities are licensing public utility poles throughout urban areas for Wi-Fi antennas that allow wireless Internet access. These systems can require hundreds of antennas in close proximity to the population with some exposures at a lateral height where second- and third-storey windows face antennas. Most of these systems are categorically excluded from regulation by the U.S. Federal Communications Commission (FCC) or oversight by government agencies because they operate below a certain power density threshold. However, power density is not the only factor determining biological effects from radiofrequency radiation (RFR).

In addition, when the U.S. and other countries permanently changed from analog signals used for television transmission to newer digital formats, the old analog frequencies were reallocated for use by municipal services such as police, fire, and emergency medical dispatch, as well as to private telecommunications companies wanting to expand their networks and services. This creates another significant increase in ambient background exposures.

Wi-Max is another wireless service in the wings that will broaden wireless capabilities further and place additional towers and (or) transmitters in close proximity to the population in addition to what is already in existence. Wi-Max aims to make wireless Internet access universal without tying the user to a specific location or ''hotspot.'' The rollout of Wi-Max in the U.S., which began in 2009, uses lower frequencies at high power densities than currently used by cellular phone transmission. Many in science and the activist communities are worried, especially those concerrned about electromagnetic-hypersensitivity syndrome (EHS).

It remains to be seen what additional exposures ''smart grid'' or ''smart meter'' technology proposals to upgrade the electrical powerline transmission systems will entail regarding total ambient RFR increases, but it will add another ubiquitous low-level layer. Some of the largest corporations on earth, notably Siemens and General Electric, are involved. Smart grids are being built out in some areas of the U.S. and in Canada and throughout Europe. That technology plans to alter certain aspects of powerline utility metering from a wired system to a partially wireless one. The systems require a combination of wireless transmitters attached to homes and businesses that will send radio signals of approximately 1 W output in the 2.4000–2.4835 GHz range to local ''access point'' transceivers, which will then relay the signal to a further distant information center (Tell 2008). Access point antennas will require additional power density and will be capable of interfacing with frequencies between 900 MHz and 1.9 GHz. Most signals will be intermittent, operating between 2 to 33 seconds per hour. Access points will be mounted on utility poles as well as on free-standing towers. The systems will form wide area networks (WANs), capable of covering whole towns and counties through a combination of ''mesh-like'' networks from house to house. Some meters installed on private homes will also act as transmission relays, boosting signals from more distant buildings in a neighborhood. Eventually, WANs will be completely linked.

Smart grid technology also proposes to allow homeowners to attach additional RFR devices to existing indoor appliances, to track power use, with the intention of reducing usage during peak hours. Manufacturers like General Electric are already making appliances with transmitters embedded in them. Many new appliances will be incapable of having transmitters deactivated without disabling the appliance and the warranty. People will be able to access their home appliances remotely by cell phone. The WANs smart grids described earlier in the text differ significantly from the current upgrades that many utility companies have initiated within recent years that already use low-power RFR meters attached to homes and businesses. Those first generation RFR meters transmit to a mobile van that travels through an area and ''collects'' the information on a regular billing cycle. Smart grids do away with the van and the meter reader and work off of a centralized RFR antenna system capable of blanketing whole regions with RFR.

Another new technology in the wings is broadband over powerlines (BPL). It was approved by the U.S. FCC in 2007 and some systems have already been built out. Critics of the latter technology warned during the approval process that radiofrequency interference could occur in homes and businesses and those warnings have proven accurate. BPL technology couples radiofrequency bands with extremely low frequency (ELF) bands that travel over powerline infrastructure, thereby creating a multi-frequency field designed to extend some distance from the lines themselves. Such couplings follow the path of conductive material, including secondary distribution lines, into people's homes.

There is no doubt that wireless technologies are popular with consumers and businesses alike, but all of this requires an extensive infrastructure to function. Infrastructure typically consists of freestanding towers (either preexisting towers to which cell antennas can be mounted, or new towers specifically built for cellular service), and myriad methods of placing transceiving antennas near the service being called for by users. This includes attaching antenna panels to the sides of buildings as well as roof-mountings; antennas hidden inside church steeples, barn silos, elevator shafts, and any number of other ''stealth sites.'' It also includes camouflaging towers to look like trees indigenous to areas where they are placed, e.g., pine trees in northern climates, cacti

[7] CTIA website: http://www.ctia.org/advocay/research/index.cfm/AID/10385. (Accessed 9 December 2008.)

in deserts, and palm trees in temperate zones, or as chimneys, flagpoles, silos, or other tall structures (Rinebold 2001). Often the rationale for stealth antenna placement or camouflaging of towers is based on the aesthetic concerns of host communities.

An aesthetic emphasis is often the only perceived control of a municipality, particularly in countries like America where there is an overriding federal preemption that precludes taking the "environmental effects" of RFR into consideration in cell tower siting as stipulated in Section 704 of *The Telecommunications Act of 1996* (USFCC 1996). Citizen resistance, however, is most often based on health concerns regarding the safety of RFR exposures to those who live near the infrastructure. Many citizens, especially those who claim to be hypersensitive to electromagnetic fields, state they would rather know where the antennas are and that hiding them greatly complicates society's ability to monitor for safety.[8]

Industry representatives try to reassure communities that facilities are many orders of magnitude below what is allowed for exposure by standards-setting boards and studies bear that out (Cooper et al. 2006; Henderson and Bangay 2006; Bornkessel et al. 2007). These include standards by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) used throughout Europe, Canada, and elsewhere (ICNIRP 1998). The standards currently adopted by the U.S. FCC, which uses a two-tiered system of recommendations put out by the National Council on Radiation Protection (NCRP) for civilian exposures (referred to as uncontrolled environments), and the International Electricians and Electronics Engineers (IEEE) for professional exposures (referred to as controlled environments) (U.S. FCC 1997). The U.S. may eventually adopt standards closer to ICNIRP. The current U.S. standards are more protective than ICNIRP's in some frequency ranges so any harmonization toward the ICNIRP standards will make the U.S. limits more lenient.

All of the standards currently in place are based on RFRs ability to heat tissue, called thermal effects. A longstanding criticism, going back to the 1950s (Levitt 1995), is that such acute heating effects do not take potentially more subtle non-thermal effects into consideration. And based on the number of citizens who have tried to stop cell towers from being installed in their neighborhoods, laypeople in many countries do not find adherence to exisitng standards valid in addressing health concerns. Therefore, infrastructure siting does not have the confidence of the public (Levitt 1998).

2. A changing industry

Cellular phone technology has changed significantly over the last two decades. The first wireless systems began in the mid-1980s and used analog signals in the 850–900 MHz range. Because those wavelengths were longer, infrastructure was needed on average every 8 to 10 miles apart. Then came the digital personal communications systems (PCS) in the late 1990s, which used higher frequencies, around 1900 GHz, and digitized signals. The PCS systems, using shorter wavelengths and with more stringent exposure guidelines, require infrastructure approximately every 1 to 3 miles apart. Digital signals work on a binary method, mimicking a wave that allows any frequency to be split in several ways, thereby carrying more information far beyond just voice messages.

Today's 3G network can send photos and download music and video directly onto a cell phone screen or iPod. The new 4G systems digitize and recycle some of the older frequencies in the 700 to 875 MHz bands to create another service for wireless Internet access. The 4G network does not require a customer who wants to log on wirelessly to locate a "hot spot" as is the case with private Wi-Fi systems. Today's Wi-Fi uses a network of small antennas, creating coverage of a small area of 100 ft (∼30 m) or so at homes or businesses. Wi-fi can also create a small wireless computer system in a school where they are often called wireless local area networks (WLANs). Whole cities can make Wi-Fi available by mounting antennas to utility poles.

Large-scale Wi-Fi systems have come under increasing opposition from citizens concerned about health issues who have legally blocked such installations (Antenna Free Union[9]). Small-scale Wi-Fi has also come under more scrutiny as governments in France and throughout Europe have banned such installations in libraries and schools, based on precautionary principles (REFLEX Program 2004).

3. Cell towers in perspective: some definitions

Cell towers are considered low-power installations when compared to many other commercial uses of radiofrequency energy. Wireless transmission for radio, television (TV), satellite communications, police and military radar, federal homeland security systems, emergency response networks, and many other applications all emit RFR, sometimes at millions of watts of effective radiated power (ERP). Cellular facilities, by contrast, use a few hundred watts of ERP per channel, depending on the use being called for at any given time and the number of service providers co-located at any given tower.

No matter what the use, once emitted, RFR travels through space at the speed of light and oscillates during propagation. The number of times the wave oscillates in one second determines its frequency.

Radiofrequency radiation covers a large segment of the electromagnetic spectrum and falls within the nonionizing bands. Its frequency ranges between 10 kHz to 300 GHz; 1 Hz = 1 oscillation per second; 1 kHz = 1000 Hz; 1 MHz = 1 000 000 Hz; and 1 GHz = 1 000 000 000 Hz.

Different frequencies of RFR are used in different applications. Some examples include the frequency range of 540 to 1600 kHz used in AM radio transmission; and 76 to 108 MHz used for FM radio. Cell-phone technology uses frequencies between 800 MHz and 3 GHz. The RFR of 2450 MHz is used in some Wi-Fi applications and microwave cooking.

Any signal can be digitized. All of the new telecommunications technologies are digitized and in the U.S., all TV is

[8] See, for example, www.radiationresearch.org. (Accessed October 2010.)
[9] http://www.antennafreeunion.org/. (Accessed October 2010.)

broadcast in 100% digital formats — digital television (DTV) and high definition television (HDTV). The old analog TV signals, primarily in the 700 MHz ranges, will now be recycled and relicensed for other applications to additional users, creating additional layers of ambient exposures.

The intensity of RFR is generally measured and noted in scientific literature in watts per square meter (W/m^2); milliwatts per square centimetre (mW/cm^2), or microwatts per square centimetre (μW/cm^2). All are energy relationships that exist in space. However, biological effects depend on how much of the energy is absorbed in the body of a living organism, not just what exists in space.

4. Specific absorption rate (SAR)

Absorption of RFR depends on many factors including the transmission frequency and the power density, one's distance from the radiating source, and one's orientation toward the radiation of the system. Other factors include the size, shape, mineral and water content of an organism. Children absorb energy differently than adults because of differences in their anatomies and tissue composition. Children are not just "little adults". For this reason, and because their bodies are still developing, children may be more susceptible to damage from cell phone radiation. For instance, radiation from a cell phone penetrates deeper into the head of children (Gandhi et al. 1996; Wiart et al. 2008) and certain tissues of a child's head, e.g., the bone marrow and the eye, absorb significantly more energy than those in an adult head (Christ et al. 2010). The same can be presumed for proximity to towers, even though exposure will be lower from towers under most circumstances than from cell phones. This is because of the distance from the source. The transmitter is placed directly against the head during cell phone use whereas proximity to a cell tower will be an ambient exposure at a distance.

There is little difference between cell phones and the domestic cordless phones used today. Both use similar frequencies and involve a transmitter placed against the head. But the newer digitally enhanced cordless technology (DECT) cordless domestic phones transmit a constant signal even when the phone is not in use, unlike the older domestic cordless phones. But some DECT brands are available that stop transmission if the mobile units are placed in their docking station.

The term used to describe the absorption of RFR in the body is specific absorption rate (SAR), which is the rate of energy that is actually absorbed by a unit of tissue. Specific absorption rates (SARs) are generally expressed in watts per kilogram (W/kg) of tissue. The SAR measurements are averaged either over the whole body, or over a small volume of tissue, typically between 1 and 10 g of tissue. The SAR is used to quantify energy absorption to fields typically between 100 kHz and 10 GHz and encompasses RFR from devices such as cellular phones up through diagnostic MRI (magnetic resonance imaging).

Specific absorption rates are a more reliable determinant and index of RFR's biological effects than are power density, or the intensity of the field in space, because SARs reflect what is actually being absorbed rather than the energy in space. However, while SARs may be a more precise model, at least in theory, there were only a handful of animal studies that were used to determine the threshold values of SAR for the setting of human exposure guidelines (de Lorge and Ezell 1980; de Lorge 1984). (For further information see Section 8). Those values are still reflected in today's standards.

It is presumed that by controlling the field strength from the transmitting source that SARs will automatically be controlled too, but this may not be true in all cases, especially with far-field exposures such as near cell or broadcast towers. Actual measurement of SARs is very difficult in real life so measurements of electric and magnetic fields are used as surrogates because they are easier to assess. In fact, it is impossible to conduct SAR measurements in living organisms so all values are inferred from dead animal measurements (thermography, calorimetry, etc.), phantom models, or computer simulation (FDTD).

However, according to the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) *Health Effects of Exposure to EMF*, released in January of 2009:

> . . . recent studies of whole body plane wave exposure of both adult and children phantoms demonstrated that when children and small persons are exposed to levels which are in compliance with reference levels, exceeding the basic restrictions cannot be excluded [Dimbylow and Bloch 2007; Wang et al. 2006; Kuhn et al., 2007; Hadjem et al., 2007]. While the whole frequency range has been investigated, such effects were found in the frequency bands around 100 MHz and also around 2 GHz. For a model of a 5-year-old child it has been shown that when the phantom is exposed to electromagnetic fields at reference levels, the basic restrictions were exceeded by 40% [Conil et al., 2008]. . .. Moreover, a few studies demonstrated that multipath exposure can lead to higher exposure levels compared to plane wave exposure [Neubauer et al. 2006; Vermeeren et al. 2007]. It is important to realize that this issue refers to far field exposure only, for which the actual exposure levels are orders of magnitude below existing guidelines. (p. 34–35, SCENIHR 2009)

In addition to average SARs, there are indications that biological effects may also depend on how energy is actually deposited in the body. Different propagation characteristics such as modulation, or different wave-forms and shapes, may have different effects on living systems. For example, the same amount of energy can be delivered to tissue continuously or in short pulses. Different biological effects may result depending on the type and duration of the exposure.

5. Transmission facilities

The intensity of RFR decreases rapidly with the distance from the emitting source; therefore, exposure to RFR from transmission towers is often of low intensity depending on one's proximity. But intensity is not the only factor. Living near a facility will involve long-duration exposures, sometimes for years, at many hours per day. People working at home or the infirm can experience low-level 24 h exposures. Nighttimes alone will create 8 h continuous exposures. The current standards for both ICNIRP, IEEE and the NCRP (adopted by the U.S. FCC) are for whole-body exposures

averaged over a short duration (minutes) and are based on results from short-term exposure studies, not for long-term, low-level exposures such as those experienced by people living or working near transmitting facilities. For such populations, these can be involuntary exposures, unlike cell phones where user choice is involved.

There have been some recent attempts to quantify human SARs in proximity to cell towers but these are primarily for occupational exposures in close proximity to the sources and questions raised were dosimetry-based regarding the accuracy of antenna modeling (van Wyk et al. 2005). In one study by Martínez-Búrdalo et al. (2005) however, the researchers used high-resolution human body models placed at different distances to assess SARs in worst-case exposures to three different frequencies — 900, 1800, and 2170 MHz. Their focus was to compute whole-body averaged SARs at a maximum 10 g averaged SAR inside the exposed model. They concluded that for

> . . . antenna–body distances in the near zone of the antenna, the fact that averaged field values are below reference levels, could, at certain frequencies, not guarantee guidelines compliance based on basic restrictions.
> (p. 4125, Martínez-Búrdalo et al. 2005)

This raises questions about the basic validity of predicting SARs in real-life exposure situations or compliance to guidelines according to standard modeling methods, at least when one is very close to an antenna.

Thus, the relevant questions for the general population living or working near transmitting facilities are: Do biological and (or) health effects occur after exposure to low-intensity RFR? Do effects accumulate over time, since the exposure is of a long duration and may be intermittent? What precisely is the definition of low-intensity RFR? What might its biological effects be and what does the science tell us about such exposures?

6. Government radiofrequency radiation (RFR) guidelines: how spatial energy translates to the body's absorption

The U.S. FCC has issued guidelines for both power density and SARs. For power density, the U.S. guidelines are between 0.2–1.0 mW/cm^2. For cell phones, SAR levels require hand-held devices to be at or below 1.6 W/kg measured over 1.0 g of tissue. For whole body exposures, the limit is 0.08 W/kg.

In most European countries, the SAR limit for hand-held devices is 2.0 W/kg averaged over 10 g of tissue. Whole body exposure limits are 0.08 W/kg.

At 100–200 ft ($\sim$30–60 m) from a cell phone base station, a person can be exposed to a power density of 0.001 mW/cm^2 (i.e., 1.0 μW/cm^2). The SAR at such a distance can be 0.001 W/kg (i.e., 1.0 mW/kg). The U.S. guidelines for SARs are between 0.08–0.40 W/kg.

For the purposes of this paper, we will define low-intensity exposure to RFR of power density of 0.001 mW/cm^2 or a SAR of 0.001 W/kg.

7. Biological effects at low intensities

Many biological effects have been documented at very low intensities comparable to what the population experiences within 200 to 500 ft ($\sim$60–150 m) of a cell tower, including effects that occurred in studies of cell cultures and animals after exposures to low-intensity RFR. Effects reported include: genetic, growth, and reproductive; increases in permeability of the blood–brain barrier; behavioral; molecular, cellular, and metabolic; and increases in cancer risk. Some examples are as follows:

- Dutta et al. (1989) reported an increase in calcium efflux in human neuroblastoma cells after exposure to RFR at 0.005 W/kg. Calcium is an important component in normal cellular functions.
- Fesenko et al. (1999) reported a change in immunological functions in mice after exposure to RFR at a power density of 0.001 mW/cm^2.
- Magras and Xenos (1997) reported a decrease in reproductive function in mice exposed to RFR at power densities of 0.000168–0.001053 mW/cm^2.
- Forgacs et al. (2006) reported an increase in serum testosterone levels in rats exposed to GSM (global system for mobile communication)-like RFR at SAR of 0.018–0.025 W/kg.
- Persson et al. (1997) reported an increase in the permeability of the blood–brain barrier in mice exposed to RFR at 0.0004–0.008 W/kg. The blood–brain barrier is a physiological mechanism that protects the brain from toxic substances, bacteria, and viruses.
- Phillips et al. (1998) reported DNA damage in cells exposed to RFR at SAR of 0.0024–0.024 W/kg.
- Kesari and Behari (2009) also reported an increase in DNA strand breaks in brain cells of rats after exposure to RFR at SAR of 0.0008 W/kg.
- Belyaev et al. (2009) reported changes in DNA repair mechanisms after RFR exposure at a SAR of 0.0037 W/kg. A list of publications reporting biological and (or) health effects of low-intensity RFR exposure is in Table 1.

Out of the 56 papers in the list, 37 provided the SAR of exposure. The average SAR of these studies at which biological effects occurred is 0.022 W/kg — a finding below the current standards.

Ten years ago, there were only about a dozen studies reporting such low-intensity effects; currently, there are more than 60. This body of work cannot be ignored. These are important findings with implications for anyone living or working near a transmitting facility. However, again, most of the studies in the list are on short-term (minutes to hours) exposure to low-intensity RFR. Long-term exposure studies are sparse. In addition, we do not know if all of these reported effects occur in humans exposed to low-intensity RFR, or whether the reported effects are health hazards. Biological effects do not automatically mean adverse health effects, plus many biological effects are reversible. However, it is clear that low-intensity RFR is not biologically inert. Clearly, more needs to be learned before a presumption of safety can continue to be made regarding placement of antenna arrays near the population, as is the case today.

Table 1. List of studies reporting biological effects at low intensities of radiofrequency radiation (RFR).

Reference	Frequency	Form of RFR	Exposure duration	SAR (W/kg)	Power density (μW/cm^2)	Effects reported
Balmori (2010) (in vivo) (eggs and tadpoles of frog)	88.5–1873.6 MHz	Cell phone base station emission	2 months		3.25	Retarded development
Belyaev et al. (2005) (in vitro)	915 MHz	GSM	24, 48 h	0.037		Genetic changes in human white blood cells
Belyaev et al. (2009) (in vitro)	915 MHz, 1947 MHz	GSM, UMTS	24, 72 h	0.037		DNA repair mechanism in human white blood cells
Blackman et al. (1980) (in vitro)	50 MHz	AM at 16 Hz		0.0014		Calcium in forebrain of chickens
Boscol et al. (2001) (in vivo) (human whole body)	500 KHz–3 GHz	TV broadcast			0.5	Immunological system in women
Campisi et al. (2010) (in vitro)	900 MHz	CW (CW– no effect observed) AM at 50 Hz	14 days, 5, 10, 20 min per day		26	DNA damage in human glial cells
Capri et al. (2004) (in vitro)	900 MHz	GSM	1 h/day, 3 days	0.07		A slight decrease in cell proliferation when human immune cells were stimulated with mitogen and a slight increase in the number of cells with altered distribution of phosphatidylserine across the membrane
Chiang et al. (1989) (in vivo) (human whole body)	Lived and worked close to AM radio and radar installations for more than 1 year				10	People lived and worked near AM radio antennas and radar installations showed deficits in psychological and short-term memory tests
de Pomerai et al. (2003) (in vitro)	1 GHz		24, 48 h	0.015		Protein damages
D'Inzeo et al. (1988) (in vitro)	10.75 GHz	CW	30–120 s	0.008		Operation of acetylcholine-related ion-channels in cells. These channels play important roles in physiological and behavioral functions
Dutta et al. (1984) (in vitro)	915 MHz	Sinusoidal AM at 16 Hz	30 min	0.05		Increase in calcium efflux in brain cancer cells
Dutta et al. (1989) (in vitro)	147 MHz	Sinusoidal AM at 16 Hz	30 min	0.005		Increase in calcium efflux in brain cancer cells
Fesenko et al. (1999) (in vivo) (mouse- wavelength in mm range)	From 8.15–18 GHz		5 h to 7 days direction of response depended on exposure duration		1	Change in immunological functions
Forgacs et al. (2006) (in vivo) (mouse whole body)	1800 MHz	GSM, 217 Hz pulses, 576 μs pulse width	2 h/day, 10 days	0.018		Increase in serum testosterone
Guler et al. (2010) (In vivo) (rabbit whole body)	1800 MHz	AM at 217 Hz	15 min/day, 7 days		52	Oxidative lipid and DNA damages in the brain of pregnant rabbits

Published by NRC Research Press

Table 1 (*continued*).

Reference	Frequency	Form of RFR	Exposure duration	SAR (W/kg)	Power density ($\mu W/cm^2$)	Effects reported
Hjollund et al. (1997) (in vivo) (human partial or whole body)	Military radars				10	Sperm counts of Danish military personnel, who operated mobile ground-to-air missile units that use several RFR emitting radar systems, were significantly lower compared to references
Ivaschuk et al. (1997) (in vitro)	836.55 MHz	TDMA	20 min	0.026		A gene related to cancer
Jech et al. (2001) (in vivo) (human partial body exposure-narcoleptic patients)	900 MHz	GSM— 217 Hz pulses, 577 µs pulse width	45 min	0.06		Improved cognitive functions
Kesari and Behari (2009) (in vivo) (rat whole body)	50 GHz		2 h/day, 45 days	0.0008		Double strand DNA breaks observed in brain cells
Kesari and Behari (2010) (in vivo) (rat whole body)	50 GHz		2 h/day, 45 days	0.0008		Reproductive system of male rats
Kesari et al. (2010) (in vivo) (rat whole body)	2450 MHz	50 Hz modulation	2 h/day, 35 days	0.11		DNA double strand breaks in brain cells
Kwee et al. (2001) (in vitro)	960 MHz	GSM	20 min	0.0021		Increased stress protein in human epithelial amnion cells
Lebedeva et al. (2000) (in vivo) (human partial body)	902.4 MHz	GSM	20 min		60	Brain wave activation
Lerchl et al. (2008) (in vivo) (hamster whole body)	383 MHz 900 and 1800 MHz	TETRA GSM	24 h/day, 60 days	0.08		Metabolic changes
Magras and Xenos (1997) (in vivo) (mouse whole body)	“Antenna park”	TV and FM-radio	Exposure over several generations		0.168	Decrease in reproductive function
Mann et al. (1998) (in vivo) (human whole body)	900 MHz	GSM pulse-modulated at 217 Hz, 577 µs width	8 h		20	A transient increase in blood cortisol
Marinelli et al. (2004) (in vitro)	900 MHz	CW	2–48 h	0.0035		Cell’s self-defense responses triggered by DNA damage
Markovà et al. (2005) (in vitro)	915 and 905 MHz	GSM	1 h	0.037		Chromatin conformation in human white blood cells
Navakatikian and Tomashevskaya (1994) (in vivo) (rat whole body)	2450 MHz 3000 MHz	CW (no effect observed) Pulse-modulated 2 µs pulses at 400 Hz	Single (0.5–12hr) or repeated (15–60 days, 7–12 h/day) exposure, CW–no effect	0.0027		Behavioral and endocrine changes, and decreases in blood concentrations of testosterone and insulin
Nittby et al. (2008) (in vivo) (rat whole body)	900 MHz,	GSM	2 h/week, 55 weeks	0.0006		Reduced memory functions
Novoselova et al. (1999) (in vivo) (mouse whole body – wavelength in mm range)	From 8.15–18 GHz		1 s sweep time – 16 ms reverse, 5 h		1	Functions of the immune system
Novoselova et al. (2004) (in vivo) (mouse whole body – wavelength in mm range)	From 8.15–18 GHz		1 s sweep time16 ms reverse, 1.5 h/day, 30 days		1	Decreased tumor growth rate and enhanced survival

Table 1 (*continued*).

Reference	Frequency	Form of RFR	Exposure duration	SAR (W/kg)	Power density ($\mu W/cm^2$)	Effects reported
Panagopoulos et al. (2010) (in vivo) (fly whole body)	900 and 1800 MHz	GSM	6 min/day, 5 days		1–10	Reproductive capacity and induced cell death
Panagopoulos and Margaritis (2010*a*) (in vivo) (fly whole body)	900 and 1800 MHz	GSM	6 min/day, 5 days		10	'Window' effect of GSM radiation on reproductive capacity and cell death
Panagopoulos and Margaritis (2010*b*) (in vivo) (fly whole body)	900 and 1800 MHz	GSM	1–21 min/day, 5 days		10	Reproductive capacity of the fly decreased linearly with increased duration of exposure
Pavicic and Trosic (2008) (in vitro)	864 and 935 MHz	CW	1–3 h	0.08		Growth affected in Chinese hamster V79 cells
Pérez-Castejón et al. (2009) (in vitro)	9.6 GHz	90% AM	24 h	0.0004		Increased proliferation rate in human astrocytoma cancer cells
Persson et al. (1997) (in vivo) (mouse whole body)	915 MHz	CW and pulse-modulated (217 Hz, 0.57 ms; 50 Hz, 6.6 ms)	2–960 min; CW more potent	0.0004		Increase in permeability of the blood–brain barrier
Phillips et al. (1998) (in vitro)	813.5625 MHz 836.55 MHz	iDEN TDMA	2, 21 h 2, 21 h	0.0024		DNA damage in human leukemia cells
Pologea-Moraru et al. (2002) (in vitro)	2.45 GHz		1 h		15	Change in membrane of cells in the retina
Pyrpasopoulou et al. (2004) (in vivo) (rat whole body)	9.4 GHz	GSM (50 Hz pulses, 20 μs pulse length)	1–7 days postcoitum	0.0005		Exposure during early gestation affected kidney development
Roux et al. (2008*a*) (in vivo) (tomato whole body)	900 MHz				7	Gene expression and energy metabolism
Roux et al. (2008*b*) (in vivo) (plant whole body)	900 MHz				7	Energy metabolism
Salford et al. (2003) (in vivo) (rat whole body)	915 MHz	GSM	2 h	0.02		Nerve cell damage in brain
Sarimov et al. (2004) (in vitro)	895–915 MHz	GSM	30 min	0.0054		Human lymphocyte chromatin affected similar to stress response
Schwartz et al. (1990) (in vitro)	240 MHz	CW and sinusoidal modulation at 0.5 and 16 Hz, effect only observed at 16 Hz modulation	30 min	0.00015		Calcium movement in the heart
Schwarz et al. (2008) (in vitro)	1950 MHz	UMTS	24 h	0.05		Genes in human fibroblasts
Somosy et al. (1991) (in vitro)	2.45 GHz	CW and 16 Hz square-modulation, modulated field more potent than CW		0.024		Molecular and structural changes in cells of mouse embryos

Table 1 (*concluded*).

Reference	Frequency	Form of RFR	Exposure duration	SAR (W/kg)	Power density (μW/cm^2)	Effects reported
Stagg et al. (1997) (in vitro)	836.55 MHz	TDMA duty cycle 33%	24 h	0.0059		Glioma cells showed significant increases in thymidine incorporation, which may be an indication of an increase in cell division
Stankiewicz et al. (2006) (in vitro)	900 MHz	GSM 217 Hz pulses, 577 ms width		0.024		Immune activities of human white blood cells
Tattersall et al. (2001) (in vitro)	700 MHz	CW	5–15 min	0.0016		Function of the hippocampus
Velizarov et al. (1999) (in vitro)	960 MHz	GSM 217 Hz square-pulse, duty cycle 12%	30 min	0.000021		Decrease in proliferation of human epithelial amnion cells
Veyret et al. (1991) (in vivo) (mouse whole body)	9.4 GHz	1 μs pulses at 1000 pps, also with or without sinusoidal AM between 14 and 41 MHz, response only with AM, direction of response depended on AM frequency		0.015		Functions of the immune system
Vian et al. (2006) (in vivo) plant	900 MHz				7	Stress gene expression
Wolke et al. (1996) (in vitro)	900, 1300, 1800 MHz 900 MHz	Square-wave modulated at 217 Hz CW, 16 Hz, 50 Hz, and 30 KHz modulations		0.001		Calcium concentration in heart muscle cells of guinea pig
Yurekli et al. (2006) (in vivo) (rat whole body)	945 MHz	GSM, 217 Hz pulse-modulation	7 h/day, 8 days	0.0113		Free radical chemistry

Note: These papers gave either specific absorption rate, SAR, (W/kg) or power density (μW/cm^2) of exposure. (Studies that did not contain these values were excluded). AM, amplitude-modulated or amplitude-modulation; CW, continuous wave; GSM, global system for mobile communication; iDEN, integrated digital enhanced network; TDMA, time division multiple access, TETRA, terrestrial trunked radio; UMTS, universal mobile telecommunications system.

8. Long-term exposures and cumulative effects

There are many important gaps in the RFR research. The majority of the studies on RFR have been conducted with short-term exposures, i.e., a few minutes to several hours. Little is known about the effects of long-term exposure such as would be experienced by people living near telecommunications installations, especially with exposures spanning months or years. The important questions then are: What are the effects of long-term exposure? Does long-term exposure produce different effects from short-term exposure? Do effects accumulate over time?

There is some evidence of cumulative effects. Phillips et al. (1998) reported DNA damage in cells after 24 h exposure to low-intensity RFR. DNA damage can lead to gene mutation that accumulates over time. Magras and Xenos (1997) reported that mice exposed to low-intensity RFR became less reproductive. After five generations of exposure the mice were not able to produce offspring. This shows that the effects of RFR can pass from one generation to another. Persson et al. (1997) reported an increase in permeability of the blood–brain barrier in mice when the energy deposited in the body exceeded 1.5 J/kg (joule per kilogram) — a measurement of the total amount of energy deposited. This suggests that a short-term, high-intensity exposure can produce the same effect as a long-term, low-intensity exposure, and is another indication that RFR effects can accumulate over time.

In addition, there is some indication that test animals become more sensitive to radiation after long-term exposure as seen in two of the critical experiments that contributed to the present SAR standards, called the "behavior–disruption experiments" carried out in the 1980s.

In the first experiment, de Lorge and Ezell (1980) trained rats on an auditory observing-response task. In the task, an animal was presented with two bars. Pressing the right bar would produce either a low-pitch or a high-pitch tone for half a second. The low-pitch tone signaled an unrewarded situation and the animal was expected to do nothing. However, when the high-pitch tone was on, pressing the left bar would produce a food reward. Thus, the task required continuous vigilance in which an animal had to coordinate its motor responses according to the stimulus presented to get a reward by choosing between a high-pitch or low-pitch tone. After learning the task, rats were then irradiated with 1280 MHz or 5620 MHz RFR during performance. Disruption of behavior (i.e., the rats could not perform very well) was observed within 30–60 min of exposure at a SAR of 3.75 W/kg for 1280 MHz, and 4.9 W/kg for 5620 MHz.

In another experiment, de Lorge (1984) trained monkeys on a similar auditory observing response task. Monkeys were exposed to RFR at 225, 1300, and 5800 MHz. Disruption of performance was observed at 8.1 mW/cm^2 (SAR 3.2 W/kg) for 225 MHz; at 57 mW/cm^2 (SAR 7.4 W/kg) for 1300 MHz; and at 140 mW/cm^2 (SAR 4.3 W/kg) for 5800 MHz. The disruption occurred when body temperature was increased by 1°C.

The conclusion from these experiments was that "... disruption of behavior occurred when an animal was exposed at an SAR of approximately 4 W/kg, and disruption occurred after 30–60 minutes of exposure and when body temperature increased by 1°C" (de Lorge 1984). Based on just these two experiments, 4 W/kg has been used in the setting of the present RFR exposure guidelines for humans. With theoretical safety margins added, the limit for occupational exposure was then set at 0.4 W/kg (i.e., 1/10 of the SAR where effects were observed) and for public exposure 0.08 W/kg for whole body exposures (i.e., 1/5 of that of occupational exposure).

But the relevant question for establishing a human SAR remains: Is this standard adequate, based on so little data, primarily extrapolated from a handful of animal studies from the same investigators? The de Lorge (1984) animal studies noted previously describe effects of short-term exposures, defined as less than one hour. But are they comparable to long-term exposures like what whole populations experience when living or working near transmitting facilities?

Two series of experiments were conducted in 1986 on the effects of long-term exposure. D'Andrea et al. (1986*a*) exposed rats to 2450 MHz RFR for 7 h a day, 7 days per week for 14 weeks. They reported a disruption of behavior at an SAR of 0.7 W/kg. And D'Andrea et al. (1986*b*) also exposed rats to 2450 MHz RFR for 7 h a day, 7 days per week, for 90 days at an SAR of 0.14 W/kg and found a small but significant disruption in behavior. The experimenters concluded, "... the threshold for behavioral and physiological effects of chronic (long-term) RFR exposure in the rat occurs between 0.5 mW/cm^2 (0.14 W/kg) and 2.5 mW/cm^2 (0.7 W/kg)" (p. 55, D'Andrea et al. 1986*b*).

The previously mentioned studies show that RFR can produce effects at much lower intensities after test animals are repeatedly exposed. This may have implications for people exposed to RFR from transmission towers for long periods of time.

Other biological outcomes have also been reported after long-term exposure to RFR. Effects were observed by Baranski (1972) and Takashima et al. (1979) after prolonged, repeated exposure but not after short-term exposure. Conversely, in other work by Johnson et al. (1983), and Lai et al. (1987, 1992) effects that were observed after short-term exposure disappeared after prolonged, repeated exposure, i.e., habituation occurred. Different effects were observed by Dumansky and Shandala (1974) and Lai et al. (1989) after different exposure durations. The conclusion from this body of work is that effects of long-term exposure can be quite different from those of short-term exposure.

Since most studies with RFR are short-term exposure studies, it is not valid to use their results to set guidelines for long-term exposures, such as in populations living or working near cell phone base stations.

9. Effects below 4 W/kg: thermal versus nonthermal

As described previously, current international RFR exposure standards are based mainly on the acute exposure experiments that showed disruption of behavior at 4 W/kg. However, such a basis is not scientifically valid. There are many studies that show biological effects at SARs less than 4 W/kg after short-term exposures to RFR. For example, since the 4 W/kg originated from psychological and (or) be-

havioral experiments, when one surveys the EMF literature on behavioral effects, one can find many reports on behavioral effects observed at SARs less than 4 W/kg, e.g., D'Andrea et al. (1986*a*) at 0.14 to 0.7 W/kg; DeWitt et al. (1987) at 0.14 W/kg; Gage (1979) at 3 W/kg ; King et al. (1971) at 2.4 W/kg; Kumlin et al. (2007) at 3 W/kg; Lai et al. (1989) at 0.6 W/kg; Mitchell et al. (1977) at 2.3 W/kg (1977); Navakatikian and Tomashevskaya (1994) at 0.027 W/kg; Nittby et al. (2008) at 0.06 W/kg; Schrot et al. (1980) at 0.7 W/kg; Thomas et al. (1975) at 1.5 to 2.7 W/kg; and Wang and Lai (2000) at 1.2 W/kg.

The obvious mechanism of effects of RFR is thermal (i.e., tissue heating). However, for decades, there have been questions about whether nonthermal (i.e., not dependent on a change in temperature) effects exist. This is a well-discussed area in the scientific literature and not the focus of this paper but we would like to mention it briefly because it has implications for public safety near transmission facilities.

Practically, we do not actually need to know whether RFR effects are thermal or nonthermal to set exposure guidelines. Most of the biological-effects studies of RFR that have been conducted since the 1980s were under nonthermal conditions. In studies using isolated cells, the ambient temperature during exposure was generally well controlled. In most animal studies, the RFR intensity used usually did not cause a significant increase in body temperature in the test animals. Most scientists consider nonthermal effects as established, even though the implications are not fully understood.

Scientifically, there are three rationales for the existence of nonthermal effects:

1. Effects can occur at low intensities when a significant increase in temperature is not likely.
2. Heating does not produce the same effects as RFR exposure.
3. RFR with different modulations and characteristics produce different effects even though they may produce the same pattern of SAR distribution and tissue heating.

Low-intensityeffects have been discussed previously (see Section 7.). There are reports that RFR triggers effects that are different from an increase in temperature, e.g., Wachtel et al. (1975); Seaman and Wachtel (1978); D'Inzeo et al. (1988). And studies showing that RFR of the same frequency and intensity, but with different modulations and waveforms, can produce different effects as seen in the work of Baranski (1972); Arber and Lin (1985); Campisi et al. (2010); d'Ambrosio et al. (2002); Frey et al. (1975); Oscar and Hawkins (1977); Sanders et al. (1985); Huber et al. (2002); Markkanen et al. (2004); Hung et al. (2007); and Luukkonen et al. (2009).

A counter-argument for point 1 is that RFR can cause micro-heating at a small location even though there is no measurement change in temperature over the whole sample. This implies that an effect observed at low intensities could be due to localized micro-heating, and, therefore, is still considered thermal. However, the micro-heating theory could not apply to test subjects that are not stationary, such as in the case of Magras and Xenos (1997) who reported that mice exposed to low-intensity RFR became less reproductive over several generations. "Hot spots" of heating move within the body when the subject moves in the field and, thus, cannot maintain sustained heating of certain tissue.

The counter argument for point 2 is that heating by other means does not produce the same pattern of energy distribution as RFR. Thus, different effects would result. Again, this counter argument does not work on moving objects. Thus, results supporting the third point are the most compelling.

10. Studies on exposure to cell tower transmissions

From the early genesis of cell phone technology in the early 1980s, cell towers were presumed safe when located near populated areas because they are low-power installations in comparison with broadcast towers. This thinking already depended on the assumption that broadcast towers were safe if kept below certain limits. Therefore, the reasoning went, cell towers would be safer still. The thinking also assumed that exposures between cell and broadcast towers were comparable. In certain cities, cell and broadcast tower transmissions both contributed significantly to the ambient levels of RFR (Sirav and Seyhan 2009; Joseph et al. 2010).

There are several fallacies in this thinking, including the fact that broadcast exposures have been found unsafe even at regulated thresholds. Adverse effects have been noted for significant increases for all cancers in both men and women living near broadcast towers (Henderson and Anderson 1986); childhood leukemia clusters (Maskarinec et al. 1994; Ha et al. 2003; Park et al. 2004); adult leukemia and lymphoma clusters, and elevated rates of mental illness (Hocking et al. 1996; Michelozzi et al. 2002; Ha et al. 2007); elevated brain tumor incidence (Dolk et al. 1997*a*, 1997*b*); sleep disorders, decreased concentration, anxiety, elevated blood pressure, headaches, memory impairment, increased white cell counts, and decreased lung function in children (Altpeter et al. 2000); motor, memory, and learning impairment in children (Kolodynski and Kolodynski 1996), nonlinear increases in brain tumor incidence (Colorado Department of Public Health 2004); increases in malignant melanoma (Hallberg and Johansson 2002); and nonlinear immune system changes in women (Boscol et al. 2001). (The term "nonlinear" is used in scientific literature to mean that an effect was not directly proportional to the intensity of exposure. In the case of the two studies mentioned previously, adverse effects were found at significant distances from the towers, not in closer proximity where the power density exposures were higher and therefore presumed to have a greater chance of causing effects. This is something that often comes up in low-level energy studies and adds credence to the argument that low-level exposures could cause qualitatively different effects than higher level exposures.)

There is also anecdotal evidence in Europe that some communities have experienced adverse physical reactions after the switch from analog TV broadcast signals to the new digital formats, which can be more biologically complex

Three doctors in Germany, Cornelia Waldmann-Selsam, MD, Christine Aschermann, MD, and Markus Kern, MD,

wrote (in a letter to the U.S. President, entitled *Warning — Adverse Health Effects From Digital Broadcast Television*)[10], that on 20 May 2006, two digital broadcast television stations went on the air in the Hessian Rhoen area. Prior to that time that area had low radiation levels, which included that from cell phone towers of which there were few. However, coinciding with the introduction of the digital signals, within a radius of more than 20 km, there was an abrupt onset of symptoms for constant headaches, pressure in the head, drowsiness, sleep problems, inability to think clearly, forgetfulness, nervousness, irritability, tightness in the chest, rapid heartbeat, shortness of breath, depression, apathy, loss of empathy, burning skin, sense of inner burning, leg weakness, pain in the limbs, stabbing pain in various organs, and weight gain. They also noted that birds fled the area. The same symptoms gradually appeared in other locations after digital signals were introduced. Some physicians accompanied affected people to areas where there was no TV reception from terrestrial sources, such as in valleys or behind mountain ranges, and observed that many people became symptom free after only a short time. The digital systems also require more transmitters than the older analog systems and, therefore, somewhat higher exposure levels to the general population are expected, according to the 2009 SCENIHR Report (SCENIHR 2009).

Whether digital or analog, the frequencies differ between broadcast and cell antennas and do not couple with the human anatomy in whole-body or organ-specific models in the same ways (NCRP 1986; ICNIRP 1998). This difference in how the body absorbs energy is the reason that all standards-setting organizations have the strictest limitations between 30–300 MHz — ranges that encompass FM broadcast where whole body resonance occurs (Cleveland 2001). Exposure allowances are more lenient for cell technology in frequency ranges between 300 MHz and 3 GHz, which encompass cellular phone technology. This is based on the assumption that the cell frequencies do not penetrate the body as deeply and no whole-body resonance can occur.

There are some studies on the health effects on people living near cell phone towers. Though cell technology has been in existence since the late 1980s, the first study of populations near cell tower base stations was only conducted by Santini et al. (2002). It was prompted in part by complaints of adverse effects experienced by residents living near cell base stations throughout the world and increased activism by citizens. As well, increasing concerns by physicians to understand those complaints was reflected in professional organizations like the ICEMS (International Committee on Electromagnetic Safety) Catania Resolution[11], the Irish Doctors Environmental Association (IDEA)[12], and the Freiburger Appeal[13].

Santini conducted a survey study of 530 people (270 men, 260 women) on 18 nonspecific health symptoms (NSHS) in relation to self-reported distance from towers of <10 m, 10 to 50 m, 50 to 100 m, 100 to 200 m, 200 to 300 m, and >300 m. The control group compared people living more than 300 m (approximately 1000 ft) or not exposed to base stations. They controlled for age, presence of electrical transformers (<10 m), high tension lines (<100 m), and radio/TV broadcast transmitters (<4 km), the frequency of cell phone use (>20 min per day), and computer use (>2 h per day). Questions also included residents' location in relation to antennas, taking into account orientations that were facing, beside, behind, or beneath antennas in cases of roof-mounted antenna arrays. Exposure conditions were defined by the length of time living in the neighborhood (<1 year through >5 years); the number of days per week and hours per day (<1 h to >16 h) that were spent in the residence.

Results indicated increased symptoms and complaints the closer a person lived to a tower. At <10 m, symptoms included nausea, loss of appetite, visual disruptions, and difficulty in moving. Significant differences were observed up through 100 m for irritability, depressive tendencies, concentration difficulties, memory loss, dizziness, and lower libido. Between 100 and 200 m, symptoms included headaches, sleep disruption, feelings of discomfort, and skin problems. Beyond 200 m, fatigue was significantly reported more often than in controls. Women significantly reported symptoms more often than men, except for libido loss. There was no increase in premature menopause in women in relation to distance from towers. The authors concluded that there were different sex-dependent sensitivities to electromagnetic fields. They also called for infrastructure not to be sited <300 m (~1000 ft) from populations for precautionary purposes, and noted that the information their survey captured might not apply to all circumstances since actual exposures depend on the volume of calls being generated from any particular tower, as well as on how radiowaves are reflected by environmental factors.

Similar results were found in Egypt by Abdel-Rassoul et al. (2007) looking to identify neurobehavioral deficits in people living near cell phone base stations. Researchers conducted a cross-sectional study of 85 subjects: 37 living inside a building where antennas were mounted on the rooftop and 48 agricultural directorate employees who worked in a building (∼10 m) opposite the station. A control group of 80 who did not live near base stations were matched for age, sex, occupation, smoking, cell phone use, and educational level. All participants completed a questionnaire containing personal, educational, and medical histories; general and neurological examinations; a neurobehavioral test battery (NBTB) involving tests for visuomotor speed, problem solving, attention, and memory, in addition to a Eysenck personality questionnaire (EPQ).

Their results found a prevalence of neuropsychiatric complaints: headaches, memory changes, dizziness, tremors, depressive symptoms, and sleep disturbance were significantly higher among exposed inhabitants than controls. The NBTB indicated that the exposed inhabitants exhibited a significantly lower performance than controls in one of the tests of attention and short-term auditory memory (paced auditory

[10] http://www.notanotherconspiracy.com/2009/02/warning-adverse-health-effects-from.html. (Accessed October 2010.)
[11] http://www.icems.eu/resolution.htm
[12] http://www.ideeaireland.org/emr.htm
[13] http://www.laleva.cc/environment/freiburger_appeal.html

JA 06274

serial addition test (PASAT)). Also, the inhabitants opposite the station exhibited a lower performance in the problem-solving test (block design) than those who lived under the station. All inhabitants exhibited a better performance in the two tests of visuomotor speed (digit symbol and Trailmaking B) and one test of attention (Trailmaking A) than controls.

Environmental power-density data were taken from measurements of that building done by the National Telecommunications Institute in 2000. Measurements were collected from the rooftop where the antennas were positioned, the shelter that enclosed the electrical equipment and cables for the antennas, other sites on the roof, and within an apartment below one of the antennas. Power-density measurements ranged from 0.1–6.7 μW/cm^2. No measurements were taken in the building across the street. The researchers noted that the last available measurements of RFR in 2002 in that area were less than the allowable standards but also noted that exposures depended on the number of calls being made at any given time, and that the number of cell phone users had increased approximately four times within the 2 years just before the beginning of their study in 2003. They concluded that inhabitants living near mobile phone base stations are at risk for developing neuropsychiatric problems, as well as some changes in the performance of neurobehavioral functions, either by facilitation (over-stimulation) or inhibition (suppression). They recommended the standards be revised for public exposure to RFR, and called for using the NBTB for regular assessment and early detection of biological effects among inhabitants near base stations (Abdel-Rassoul et al. 2007).

Hutter et al. (2006) sought to determine cognitive changes, sleep quality, and overall well-being in 365 rural and urban inhabitants who had lived for more than a year near 10 selected cell phone base stations. Distance from antennas was 24 to 600 m in rural areas, and 20 to 250 m in the urban areas. Field strength measurements were taken in bedrooms and cognitive tests were performed. Exposure to high-frequency EMFs was lower than guidelines and ranged from 0.000002 to 0.14 μW/cm^2 for all frequencies between 80 MHz and 2 GHz with the greater exposure coming from mobile telecommunications facilities, which was between 0.000001 and 0.14 μW/cm^2. Maximum levels were between 0.000002 and 0.41 μW/cm^2 with an overall 5% of the estimated maximum above 0.1 μW/cm^2. Average levels were slightly higher in rural areas (0.005 μW/cm^2) than in urban areas (0.002 μW/cm^2). The researchers tried to ascertain if the subjective rating of negative health consequences from base stations acted as a covariable but found that most subjects expressed no strong concerns about adverse effects from the stations, with 65% and 61% in urban and rural areas, respectively, stating no concerns at all. But symptoms were generally higher for subjects who expressed health concerns regarding the towers. The researchers speculated that this was due to the subjects with health complaints seeking answers and consequently blaming the base station; or that subjects with concerns were more anxious in general and tended to give more negative appraisals of their body functions; and the fact that some people simply give very negative answers.

Hutter's results were similar to those of Santini et al. (2002) and Abdel-Rassoul et al. (2007). Hutter found a significant relationship between symptoms and power densities. Adverse effects were highest for headaches, cold hands and feet, cardiovascular symptoms, and concentration difficulties. Perceptual speed increased while accuracy decreased insignificantly with increasing exposure levels. Unlike the others, however, Hutter found no significant effects on sleep quality and attributed such problems more to fear of adverse effects than actual exposure. They concluded that effects on well-being and performance cannot be ruled out even as mechanisms of action remain unknown. They further recommended that antenna siting should be done to minimize exposure to the population.

Navarro et al. (2003) measured the broadband electric field (E-field) in the bedrooms of 97 participants in La Nora, Murcia, Spain and found a significantly higher symptom score in 9 out of 16 symptoms in the groups with an exposure of 0.65 V/m (0.1121 μW/cm^2) compared with the control group with an exposure below 0.2 V/m (0.01061 μW/cm^2), both as an average. The highest contributor to the exposure was GSM 900/1800 MHz signals from mobile telecommunications. The same researchers also reported significant correlation coefficients between the measured E-field and 14 out of 16 health-related symptoms with the five highest associations found for depressive tendencies, fatigue, sleeping disorders, concentration difficulties, and cardiovascular problems. In a follow up work, Oberfeld et al. (2004) conducted a health survey in Spain in the vicinity of two GSM 900/1800 MHz cell phone base stations, measuring the E-field in six bedrooms, and found similar results. They concluded that the symptoms are in line with "microwave syndrome" reported in the literature (Johnson-Liakouris 1998). They recommended that the sum total for ambient exposures should not be higher than 0.02 V/m — the equivalent of a power density of 0.00011 μW/cm^2, which is the indoor exposure value for GSM base stations proposed by the Public Health Office of the Government of Salzburg, Austria in 2002[14].

Eger et al. (2004) took up a challenge to medical professionals by Germany's radiation protection board to determine if there was an increased cancer incidence in populations living near cell towers. Their study evaluated data for approximately 1000 patients between the years of 1994 and 2004 who lived close to cell antennas. The results showed that the incidence of cancer was significantly higher among those patients who had lived for 5 to 10 years at a distance of up to 400 m from a cell installation that had been in operation since 1993, compared with those patients living further away, and that the patients fell ill on an average of 8 years earlier than would be expected. In the years between 1999 and 2004, after 5 years operation of the transmitting installation, the relative risk of getting cancer had tripled for residents in proximity of the installation compared with inhabitants outside of the area.

Wolf and Wolf (2004) investigated increased cancer incidence in populations living in a small area in Israel exposed

[14] http://www.salzburg.gv.at/umweltmedizin. (Accessed October 2010.)

to RFR from a cell tower. The antennas were mounted 10 m high, transmitting at 850 MHz and 1500 W at full-power output. People lived within a 350 m half circle of the antennas. An epidemiologic assessment was done to determine whether the incidence of cancer cases among individuals exposed to the base station in the south section of the city of Netanya called Irus (designated area A) differed from expected cancer rates throughout Israel, and in the town of Netanya in general, as compared with people who lived in a nearby area without a cell tower (designated area B). There were 622 participants in area A who had lived near the cell tower for 3 to 7 years and were patients at one health clinic. The exposure began 1 year before the start of the study when the station first came into service. A second cohort of individuals in area B, with 1222 participants who received medical services at a different clinic located nearby, was used as a control. Area B was closely matched for environment, workplace, and occupational characteristics. In exposure area A, eight cases of different types of cancer were diagnosed in a period of 1 year, including cancers of the ovary (1), breast (3), Hodgkins lymphoma (1), lung (1), osteoid osteoma (1), and hypernephroma (1). The RFR field measurements were also taken per house and matched to the cancer incidents. The rate of cancers in area A was compared with the annual rate of the general population (31 cases per 10 000) and to incidence for the entire town of Netanya. There were two cancers in area B, compared to eight in area A. They also examined the history of the exposed cohort (area A) for malignancies in the 5 years before exposure began and found only two cases in comparison to eight cases 1 year after the tower went into service. The researchers concluded that relative cancer rates for females were 10.5 for area A, 0.6 for area B, and 1.0 for the whole town of Netanya. Cancer incidence in women in area A was thus significantly higher ($p < 0.0001$) compared with that of area B and the whole city. A comparison of the relative risk revealed that there were 4.15 times more cases in area A than in the entire population. The study indicated an association between increased incidence of cancer and living in proximity to a cell phone base station. The measured level of RFR, between 0.3 to 0.5 $\mu W/cm^2$, was far below the thermal guidelines.

11. Risk perception, electrohypersensitivity, and psychological factors

Others have followed up on what role risk perception might play in populations near cell base stations to see if it is associated with health complaints.

Blettner et al. (2008) conducted a cross-sectional, multiphase study in Germany. In the initial phase, 30 047 people out of a total of 51 444, who took part in a nationwide survey, were also asked about their health and attitudes towards mobile phone base stations. A list of 38 potential health complaints were used. With a response rate of 58.6%, 18.0% were concerned about adverse health effects from base stations, 10.3% directly attributed personal adverse effects to them. It was found that people living within 500 m, or those concerned about personal exposures, reported more health complaints than others. The authors concluded that even though a substantial proportion of the German population is concerned about such exposures, the observed higher health complaints cannot be attributed to those concerns alone.

Kristiansen et al. (2009) also explored the prevalence and nature of concerns about mobile phone radiation, especially since the introduction of new 3G–UMTS (universal mobile telecommunications system) networks that require many more towers and antennas have sparked debate throughout Europe. Some local governments have prohibited mobile antennas on public buildings due to concerns about cancer, especially brain cancer in children and impaired psychomotor functions. One aim of the researchers was risk assessment — to compare people's perceptions of risk from cell phones and masts to other fears, such as being struck by lightening. In Denmark, they used data from a 2006 telephone survey of 1004 people aged 15+ years. They found that 28% of the respondents were concerned about exposure to mobile phone radiation and 15% about radiation from masts. In contrast, 82% of respondents were concerned about other forms of environmental pollution. Nearly half of the respondents considered the mortality risk of 3G phones and masts to be of the same order of magnitude as being struck by lightning (0.1 fatalities per million people per year), while 7% thought it was equivalent to tobacco-induced lung cancer (approximately 500 fatalities per million per year). Among women, concerns about mobile phone radiation, perceived mobile phone mortality risk, and concerns about unknown consequences of new technologies, increased with educational levels. More than two thirds of the respondents felt that they had not received adequate public information about the 3G system. The results of the study indicated that the majority of the survey population had little concern about mobile phone radiation, while a minority is very concerned.

Augner et al. (2009) examined the effects of short-term GSM base station exposure on psychological symptoms including good mood, alertness, and calmness as measured by a standardized well-being questionnaire. Fifty-seven participants were randomly assigned to one of three different exposure scenarios. Each of those scenarios subjected participants to five 50 min exposure sessions, with only the first four relevant for the study of psychological symptoms. Three exposure levels were created by shielding devices, which could be installed or removed between sessions to create double-blinded conditions. The overall median power densities were 0.00052 $\mu W/cm^2$ during low exposures, 0.0154 $\mu W/cm^2$ during medium exposures, and 0.2127 $\mu W/cm^2$ during high-exposure sessions. Participants in high- and medium-exposure scenarios were significantly calmer during those sessions than participants in low-exposure scenarios throughout. However, no significant differences between exposure scenarios in the "good mood" or "alertness" factors were found. The researchers concluded that short-term exposure to GSM base station signals may have an impact on well-being by reducing psychological arousal.

Eltiti et al. (2007) looked into exposures to the GSM and UMTS exposures from base stations and the effects to 56 participants who were self-reported as sensitive to electromagnetic fields. Some call it electro-hypersensitivity (EHS) or just electrosensitivity. People with EHS report that they suffer negative health effects when exposed to electro-

magnetic fields from everyday objects such as cell phones, mobile phone base stations, and many other common things in modern societies. EHS is a recognized functional impairment in Sweden. This study used both open provocation and double-blind tests to determine if electrosensitive and control individuals experienced more negative health effects when exposed to base-station-like signals compared with sham exposures. Fifty-six electrosensitive and 120 control participants were tested first in an open provocation test. Of these, 12 electrosensitive and six controls withdrew after the first session. Some of the electrosensitive subjects later issued a statement saying that the initial exposures made them too uncomfortable to continue participating in the study. This means that the study may have lost its most vulnerable test subjects right at the beginning, possibly skewing later outcomes. The remainder completed a series of double-blind tests. Subjective measures of well-being and symptoms, as well as physiological measures of blood-volume pulse, heart rate, and skin conductance were obtained. They found that during the open provocation, electrosensitive individuals reported lower levels of well-being to both GSM and UMTS signals compared with sham exposure, whereas controls reported more symptoms during the UMTS exposure. During double-blind tests the GSM signal did not have any effect on either group. Electrosensitive participants did report elevated levels of arousal during the UMTS condition, but the number or severity of symptoms experienced did not increase. Physiological measures did not differ across the three exposure conditions for either group. The researchers concluded that short-term exposure to a typical GSM base-station-like signal did not affect well-being or physiological functions in electrosensitive or control individuals even though the electrosensitive individuals reported elevated levels of arousal when exposed to a UMTS signal. The researchers stated that this difference was likely due to the effect of the order of the exposures throughout the series rather than to the exposure itself. The researchers do not speculate about possible data bias when one quarter of the most sensitive test subjects dropped out at the beginning.

In follow-up work, Eltiti et al. (2009) attempted to clarify some of the inconsistencies in the research with people who report sensitivity to electromagnetic fields. Such individuals, they noted, often report cognitive impairments that they believe are due to exposure to mobile phone technology. They further said that previous research in this area has revealed mixed results, with the majority of research only testing control individuals. Their aim was to clarify whether short-term (50 min) exposure at 1 μW/cm^2 to typical GSM and UMTS base station signals affects attention, memory, and physiological endpoints in electrosensitive and control participants. Data from 44 electrosensitive and 44 matched-control participants who performed the digit symbol substitution task (DSST), digit span task (DS), and a mental arithmetic task (MA), while being exposed to GSM, UMTS, and sham signals under double-blind conditions were analyzed. Overall, the researchers concluded that cognitive functioning was not affected by short-term exposure to either GSM or UMTS signals. Nor did exposure affect the physiological measurements of blood-volume pulse, heart rate, and skin conductance that were taken while participants performed the cognitive tasks. The GSM signal was a combined signal of 900 and 1800 MHz frequencies, each with a power flux density of 0.5 μW/cm^2, which resulted in combined power flux density of 1 μW/cm^2 over the area where test subjects were seated. Previous measurements in 2002 by the National Radiological Protection Board in the UK, measuring power density from base stations at 17 sites and 118 locations (Mann et al. 2002), found that in general, the power flux density was between 0.001 μW/cm^2 to 0.1 μW/cm^2, with the highest power density being 0.83 μW/cm^2. The higher exposure used by the researchers in this study was deemed comparable by them to the maximum exposure a person would encounter in the real world. But many electrosensitive individuals report that they react to much lower exposures too. Overall, the electrosensitive participants had a significantly higher level of mean skin conductance than control subjects while performing cognitive tasks. The researchers noted that this was consistent with other studies that hypothesize sensitive individuals may have a general imbalance in autonomic nervous system regulation. Generally, cognitive functioning was not affected in either electrosensitives or controls. When Bonferroni corrections were applied to the data, the effects on mean skin conductance disappeared. A criticism is that this averaging of test results hides more subtle effects.

Wallace et al. (2010) also tried to determine if short-term exposure to RFR had an impact on well-being and what role, if any, psychological factors play. Their study focused on “Airwave”, a new communication system being rolled out across the UK for police and emergency services. Some police officers have complained about skin rashes, nausea, headaches, and depression as a consequence of using Airwave two-way radio handsets. The researchers used a small group of self-reported electrosensitive people to determine if they reacted to the exposures, and to determine if exposures to specific signals affect a selection of the adult population who do not report sensitivity to electromagnetic fields. A randomized double-blind provocation study was conducted to establish whether short-term exposure to a terrestrial trunked radio (TETRA) base station signal has an impact on health and well-being in individuals with electrosensitivity and controls. Fifty-one individuals with electrosensitivity and 132 age- and gender-matched controls participated first in an open provocation test, while 48 electrosensitive and 132 control participants went on to complete double-blind tests in a fully screened semi-anechoic chamber. Heart rate, skin conductance, and blood pressure readings provided objective indices of short-term physiological response. Visual analogue scales and symptom scales provided subjective indices of well-being. Their results found no differences on any measure between TETRA and sham (no signal) under double-blind conditions for either control or electrosensitive participants and neither group could detect the presence of a TETRA signal above chance (50%). The researchers noted, however, that when conditions were not double-blinded, the electrosensitive individuals did report feeling worse and experienced more severe symptoms during TETRA compared with sham exposure. They concluded that the adverse symptoms experienced by electrosensitive individuals are caused by the belief of harm from TETRA base stations rather than because of the low-level EMF exposure itself.

It is interesting to note that the three previously men-

tioned studies were all conducted at the same Electromagnetics and Health Laboratory at the University of Essex, Essex, UK, by the same relative group of investigators. Those claiming to be electrosensitive are a small subgroup in the population, often in touch through Internet support groups. In the first test, many electrosensitives dropped out because they found the exposures used in the study too uncomfortable. The drop-out rate decreased with the subsequent studies, which raises the question of whether the electrosensitive participants in the latter studies were truly electrosensitive. There is a possibility that a true subgroup of electrosensitives cannot tolerate such study conditions, or that potential test subjects are networking in a way that preclude their participation in the first place. In fact, researchers were not able to recruit their target numbers for electrosensitive participants in any of the studies. The researchers also do not state if there were any of the same electrosensitive participants used in the three studies. Nor do they offer comment regarding the order of the test methods possibly skewing results.

Because of uncertainty regarding whether EMF exposures are actually causing the symptoms that electrosensitives report, and since many electrosensitives also report sensitivities to myriad chemicals and other environmental factors, it has been recommended (Hansson Mild et al. 2006) that a new term be used to describe such individuals — idiopathic environmental intolerance with attribution to electromagnetic fields (IEI-EMF).

Furubayashi et al. (2009) also tried to determine if people who reported symptoms to mobile phones are more susceptible than control subjects to the effect of EMF emitted from base stations. They conducted a double-blind, cross-over provocation study, sent questionnaires to 5000 women and obtained 2472 valid responses from possible candidates. From those, they were only able to recruit 11 subjects with mobile phone related symptoms (MPRS) and 43 controls. The assumption was that individuals with MPRS matched the description of electrosensitivity by the World Health Organization (WHO). There were four EMF exposure conditions, each of which lasted 30 min: (*i*) continuous, (*ii*) intermittent, (*iii*) sham exposure with noise, and (*iv*) sham exposure without noise. Subjects were exposed to EMF of 2.14 GHz, 10 V/m (26.53 μW/cm^2) wideband code division multiple access (W-CDMA), in a shielded room to simulate whole-body exposure to EMF from base stations, although the exposure strength they used was higher than that commonly received from base stations. The researchers measured several psychological and cognitive parameters immediately before and after exposure, and monitored autonomic functions. Subjects were asked to report on their perception of EMF and level of discomfort during the experiment. The MPRS group did not differ from the controls in their ability to detect exposure to EMF. They did, however, consistently experience more discomfort in general, regardless of whether or not they were actually exposed to EMF, and despite the lack of significant changes in their autonomic functions. The researchers noted that others had found electrosensitive subjects to be more susceptible to stress imposed by task performance, although they did not differ from normal controls in their personality traits. The researchers concluded that the two groups did not differ in their responses to real or sham EMF exposure according to any psychological, cognitive or autonomic assessment. They said they found no evidence of any causal link between hypersensitivity symptoms and exposure to EMF from base stations. However, this study, had few MPRS participants.

Regel et al. (2006) also investigated the effects of the influence of UMTS base-station-like signals on well-being and cognitive performance in subjects with and without self-reported sensitivity to RFR. The researchers performed a controlled exposure experiment in a randomized, double-blind crossover study, with 45 min at an electric field strength of 0 V/m, 1.0 V/m (0.2653 μW/cm^2), or 10.0 V/m (26.53 μW/cm^2), incident with a polarization of 45° from the left-rear side of the subject, at weekly intervals. A total of 117 healthy subjects that included 33 self-reported sensitive subjects and 84 nonsensitive subjects, participated in the study. The team assessed well-being, perceived field strength, and cognitive performance with questionnaires and cognitive tasks and conducted statistical analyses using linear mixed models. Organ-specific and brain-tissue-specific dosimetry, including uncertainty and variation analysis, was performed. Their results found that in both groups, well-being and perceived field strength were not associated with actual exposure levels. They observed no consistent condition-induced changes in cognitive performance except for two marginal effects. At 10 V/m (26.53 μW/cm^2) they observed a slight effect on speed in one of six tasks in the sensitive subjects and an effect on accuracy in another task in nonsensitive subjects. Both effects disappeared after multiple endpoint adjustments. They concluded that they could not confirm a short-term effect of UMTS base-station-like exposure on well-being. The reported effects on brain functioning were marginal, which they attributed to chance. Peak spatial absorption in brain tissue was considerably smaller than during use of a mobile phone. They concluded that no conclusions could be drawn regarding short-term effects of cell phone exposure or the effects of long-term base-station-like exposures on human health.

Siegrist et al. (2005) investigated risk perceptions associated with mobile phones, base stations, and other sources of EMFs through a telephone survey conducted in Switzerland. Participants assessed both risks and benefits associated with nine different sources of EMF. Trust in the authorities regulating these hazards was also assessed. Participants answered a set of questions related to attitudes toward EMF and toward mobile phone base stations. Their results were: high-voltage transmission lines are perceived as the most risky source of EMF; and mobile phones and base stations received lower risk ratings. Trust in authorities was positively associated with perceived benefits and negatively associated with perceived risks. Also, people who use their mobile phones frequently perceived lower risks and higher benefits than people who use their mobile phones infrequently. People who believed they lived close to a base station did not significantly differ in their perceived level of risks associated with mobile phone base stations from people who did not believe they lived close to a base station. A majority of participants favored limits to exposures based on worst-case scenarios. The researchers also correlated perceived risks with other beliefs and found that belief in paranormal phenomena is related to level of perceived risks associated with

EMF. In addition, people who believed that most chemical substances cause cancer also worried more about EMF than people who did not believe that chemical substances are harmful. This study found the obvious — that some people worry more about environmental factors than others across a range of concerns.

Wilen et al. (2006) investigated the effects of exposure to mobile phone RFR on people who experience subjective symptoms when using mobile phones. Twenty subjects with MPRS were matched with 20 controls without MPRS. Each subject participated in two experimental sessions, one with true exposure and one with sham exposure, in random order. In the true exposure condition, the test subjects were exposed for 30 min to an RFR field generating a maximum SAR (1 g) in the head of 1 W/kg through an indoor base station antenna attached to signals from a 900 MHz GSM mobile phone. Physiological and cognitive parameters were measured during the experiment for heart rate and heart rate variability (HRV), respiration, local blood flow, electrodermal activity, critical flicker fusion threshold (CFFT), short-term memory, and reaction time. No significant differences related to RFR exposure conditions and no differences in baseline data were found between subject groups with the exception for reaction time, which was significantly longer among the test subjects than among the controls the first time the test was performed. This difference disappeared when the test was repeated. However, the test subjects differed significantly from the controls with respect to HRV as measured in the frequency domain. The test subjects displayed a shift in the low/high frequency ratio towards a sympathetic dominance in the autonomous nervous system during the CFFT and memory tests, regardless of exposure condition. They interpreted this as a sign of differences in the autonomous nervous system regulation among persons with MPRS and persons with no such symptoms.

12. Assessing exposures

Quantifying, qualifying, and measuring radiofrequency (RF) energy both indoors and outdoors has frustrated scientists, researchers, regulators, and citizens alike. The questions involve how best to capture actual exposure data — through epidemiology, computer estimates, self-reporting, or actual dosimetry measurements. Determining how best to do this is more important than ever, given the increasing background levels of RFR. Distance from a generating source has traditionally been used as a surrogate for probable power density but that is imperfect at best, given how RF energy behaves once it is transmitted. Complicated factors and numerous variables come into play. The wearing of personal dosimetry devices appears to be a promising area for capturing cumulative exposure data.

Neubauer et al. (2007) asked the question if epidemiology studies are even possible now, given the increasing deployment of wireless technologies. They examined the methodological challenges and used experts in engineering, dosimetry, and epidemiology to critically evaluate dosimetric concepts and specific aspects of exposure assessment regarding epidemiological study outcomes. They concluded that, at least in theory, epidemiology studies near base stations are feasible but that all relevant RF sources have to be taken into account. They called for pilot studies to validate exposure assessments and recommended that short-to-medium term effects on health and well-being are best investigated by cohort studies. They also said that for long-term effects, groups with high exposures need to be identified first, and that for immediate effects, human laboratory studies are the preferred approach. In other words, multiple approaches are required. They did not make specific recommendations on how to quantify long-term, low-level effects on health and well-being.

Radon et al. (2006) compared personal RF dosimetry measurements against recall to ascertain the reliability of self-reporting near base stations. Their aim was to test the feasibility and reliability of personal dosimetry devices. They used a 24 h assessment on 42 children, 57 adolescents, and 64 adults who wore a Maschek dosimeter prototype, then compared the self-reported exposures with the measurements. They also compared the readings of Maschek prototype with those of the Antennessa DSP-090 in 40 test subjects. They found that self-reported exposures did not correlate with actual readings. The two dosimeters were in moderate agreement. Their conclusion was that personal dosimetry, or the wearing of measuring devices, was a feasible method in epidemiology studies.

A study by Frei et al. (2009) also used personal dosimetry devices to examine the total exposure levels of RFR in the Swiss urban population. What they found was startling — nearly a third of the test subjects' cumulative exposures were from cell base stations. Prior to this study, exposure from base stations was thought to be insignificant due to their low-power densities and to affect only those living or working in close proximity to the infrastructure. This study showed that the general population moves in and out of these particular fields with more regularity than previously expected. In a sample of 166 volunteers from Basel, Switzerland, who agreed to wear personal exposure meters (called exposimeters), the researchers found that nearly one third of total exposures came from base stations. Participants carried an exposimeter for 1 week (2 separate weeks in 32 participants) and also completed an activity diary. Mean values were calculated using the robust regression on order statistics (ROS) method. Results found a mean weekly exposure to all RFR and (or) EMF sources was 0.013 $\mu W/cm^2$ (range of individual means 0.0014–0.0881 $\mu W/cm^2$). Exposure was mainly from mobile phone base stations (32.0%), mobile phone handsets (29.1%), and digital enhanced cordless telecommunications (DECT) phones (22.7%). People owning a DECT phone (total mean 0.015 $\mu W/cm^2$) or mobile phone (0.014 $\mu W/cm^2$) were exposed more than those not owning a DECT or mobile phone (0.010 $\mu W/cm^2$). Mean values were highest in trains (0.116 $\mu W/cm^2$), airports (0.074 $\mu W/cm^2$), and tramways or buses (0.036 $\mu W/cm^2$) and were higher during daytime (0.016 $\mu W/cm^2$) than nighttime (0.008 $\mu W/cm^2$). The Spearman correlation coefficient between mean exposure in the first and second week was 0.61. Another surprising finding of this study contradicted Neubauer et al. (2008) who found that a rough dosimetric estimate of a 24 h exposure from a base station (1–2 V/m) (i.e., 0.2653–1.061 $\mu W/cm^2$) corresponded to approximately 30 min of mobile phone use. But Frei et al. (2009) found, using the exposimeter, that cell phone use was 200 times higher than the average base sta-

tion exposure contribution in self-selected volunteers (0.487 versus 0.002 μW/cm²). This implied that at the belt, backpack, or in close vicinity to the body, the mean base station contribution corresponds to about 7 min of mobile phone use (24 h divided by 200), not 30 min. They concluded that exposure to RFR varied considerably between persons and locations but was fairly consistent for individuals. They noted that cell phones, base stations, and cordless phones were important sources of exposure in urban Switzerland but that people could reduce their exposures by replacing their cordless domestic phones with conventional landlines at home. They determined that it was feasible to combine diary data with personal exposure measurements and that such data was useful in evaluating RFR exposure during daily living, as well as helpful in reducing exposure misclassification in future epidemiology studies.

Viel et al. (2009) also used personal exposure meters (EME SPY 120 made by Satimo and ESM 140 made by Maschek) to characterize actual residential exposure from antennas. Their primary aim was to assess personal exposures, not ambient field strengths. Two hundred randomly selected people were enrolled to wear measurement meters for 24 h and asked to keep a time–location–activity diary. Two exposure metrics for each radiofrequency were then calculated: the proportion of measurements above the detection limit of 0.05 V/m (0.0006631 μW/cm²) and the maximum electric field strength. Residential addresses were geocoded and distances from each antenna were calculated. They found that much of the time-recorded field strength was below the detection level of 0.05 V/m, with the exception of the FM radio bands, which had a detection threshold of 12.3%. The maximum electric field was always lower than 1.5 V/m (0.5968 μW/cm²). Exposure to GSM and digital cellular system (DCS) frequencies peaked around 280 m in urban areas and 1000 m from antennas in more suburban/rural areas. A downward trend in exposures was found within a 10 km distance for FM exposures. Conversely, UMTS, TV3, and TV 4 and 5 signals did not vary with distance. The difference in peak exposures for cell frequencies were attributed to microcell antennas being more numerous in urban areas, often mounted a few meters above ground level, whereas macrocell base stations in less urban areas are placed higher (between 15 and 50 m above ground level) to cover distances of several kilometres. They concluded that despite the limiting factors and high variability of RF exposure assessments, in using sound statistical technique they were able to determine that exposures from GSM and DCS cellular base stations actually increase with distance in the near source zone, with a maximum exposure where the main beam intersects the ground. They noted that such information should be available to local authorities and the public regarding the siting of base stations. Their findings coincide with Abdel-Rassoul et al. (2007) who found field strengths to be less in the building directly underneath antennas, with reported health complaints higher in inhabitants of the building across the street.

Amoako et al. (2009) conducted a survey of RFR at public access points close to schools, hospitals, and highly populated areas in Ghana near 50 cell phone base stations. Their primary objective was to measure and analyze field strength levels. Measurements were made using an Anritsu model MS 2601A spectrum analyzer to determine the electric field level in the 900 and 1800 MHz frequency bands. Using a GPS (global positioning system), various base stations were mapped. Measurements were taken at 1.5 m above ground to maintain line of sight with the RF source. Signals were measured during the day over a 3 h period, at a distance of approximately 300 m. The results indicated that power densities for 900 MHz at public access points varied from as low as 0.000001 μW/cm² to as high as 0.001 μW/cm². At 1800 MHz, the variation of power densities was from 0.000001 to 0.01 μW/cm². There are no specific RFR standards in Ghana. These researchers determined that while their results in most cites were compliant with the ICNIRP standards, levels were still 20 times higher than values typically found in the UK, Australia, and the U.S., especially for Ghana base stations in rural areas with higher power output. They determined that there is a need to reduce RFR levels since an increase in mobile phone usage is foreseen.

Clearly, predicting actual exposures based on simple distance from antennas using standardized computer formulas is inadequate. Although power density undoubtedly decreases with distance from a generating source, actual exposure metrics can be far more complex, especially in urban areas. Contributing to the complexity is the fact that the narrow vertical spread of the beam creates a low RF field strength at the ground directly below the antenna. As a person moves away or within a particular field, exposures can become complicated, creating peaks and valleys in field strength. Scattering and attenuation alter field strength in relation to building placement and architecture, and local perturbation factors can come into play. Power density levels can be 1 to 100 times lower inside a building, depending on construction materials, and exposures can differ greatly within a building, depending on numerous factors such as orientation toward the generating source and the presence of conductive materials. Exposures can be twice as high in upper floors than in lower floors, as found by Anglesio et al. (2001).

However, although distance from a transmitting source has been shown to be an unreliable determinant for accurate exposure predictions, it is nevertheless useful in some general ways. For instance, it has been shown that radiation levels from a tower with 15 nonbroadcast radio systems will fall off to hypothetical natural background levels at approximately 1500 ft (∼500 m) (Rinebold 2001). This would be in general agreement with the lessening of symptoms in people living near cell towers at a distance over 1000 ft (∼300 m) found by Santini et al. (2002) .

The previously mentioned studies indicate that accuracy in both test design and personal dosimetry measurements are possible in spite of the complexities and that a general safer distance from a cell tower for residences, schools, daycare centers, hospitals, and nursing homes might be ascertained.

13. Discussion

Numerous biological effects do occur after short-term exposures to low-intensity RFR but potential hazardous health effects from such exposures on humans are still not well es-

tablished, despite increasing evidence as demonstrated throughout this paper. Unfortunately, not enough is known about biological effects from long-term exposures, especially as the effects of long-term exposure can be quite different from those of short-term exposure. It is the long-term, low-intensity exposures that are most common today and increasing significantly from myriad wireless products and services.

People are reporting symptoms near cell towers and in proximity to other RFR-generating sources including consumer products such as wireless computer routers and Wi-Fi systems that appear to be classic "microwave sickness syndrome," also known as "radiofrequency radiation sickness." First identified in the 1950s by Soviet medical researchers, symptoms included headache, fatigue, ocular dysfunction, dizziness, and sleep disorders. In Soviet medicine, clinical manifestations include dermographism, tumors, blood changes, reproductive and cardiovascular abnormalities, depression, irritability, and memory impairment, among others. The Soviet researchers noted that the syndrome is reversible in early stages but is considered lethal over time (Tolgskaya et al. 1973).

Johnson-Liakouris (1998) noted there are both occupational studies conducted between 1953 and 1991 and clinical cases of acute exposure between 1975 and 1993 that offer substantive verification for the syndrome. Yet, U.S. regulatory agencies and standards-setting groups continue to quibble about the existence of microwave sickness because it does not fit neatly into engineering models for power density, even as studies are finding that cell towers are creating the same health complaints in the population. It should be noted that before cellular telecommunications technology, no such infrastructure exposures between 800 MHz and 2 GHz existed this close to so many people. Microwave ovens are the primary consumer product utilizing a high RF intensity, but their use is for very brief periods of time and ovens are shielded to prevent leakage above 1000 $\mu W/cm^2$ — the current FDA standard. In some cases, following the U.S. Telecommunications Act of 1996 preemption of local health considerations in infrastructure siting, antennas have been mounted within mere feet of dwellings. And, on buildings with roof-mounted arrays, exposures can be lateral with top floors of adjacent buildings at close range.

It makes little sense to keep denying health symptoms that are being reported in good faith. Though the prevalence of such exposures is relatively new to a widespread population, we, nevertheless, have a 50 year observation period to draw from. The primary questions now involve specific exposure parameters, not the reality of the complaints or attempts to attribute such complaints to psychosomatic causes, malingering, or beliefs in paranormal phenomenon. That line of argument is insulting to regulators, citizens, and their physicians. Serious mitigation efforts are overdue.

There is early Russian and U.S. documentation of long-term, very low-level exposures causing microwave sickness as contained in *The Johns Hopkins Foreign Service Health Status Study* done in 1978 (Lilienfield et al. 1978; United States Senate 1979). This study contains both clinical information, and clear exposure parameters. Called the Lilienfield study, it was conducted between 1953 and 1976 to determine what, if any, effects there had been to personnel in the U.S. Embassy in Moscow after it was discovered that the Soviet government had been systematically irradiating the U.S. government compound there.

The symptoms reported were not due to any known tissue heating properties. The power densities were not only very low but the propagation characteristics were remarkably similar to what we have today with cell phone base stations. Lilienfield recorded exposures for continuous-wave, broadband, modulated RFR in the frequency ranges between 0.6 and 9.5 GHz. The exposures were long-term and low-level at 6 to 8 h per day, 5 days per week, with the average length of exposure time per individual between 2 to 4 years. Modulation information contained phase, amplitude, and pulse variations with modulated signals being transmitted for 48 h or less at a time. Radiofrequency power density was between 2 and 28 $\mu W/cm^2$ — levels comparable to recent studies cited in this paper.

The symptoms that Lilienfield found included four that fit the Soviet description for dermographism — eczema, psoriasis, allergic, and inflammatory reactions. Also found were neurological problems with diseases of peripheral nerves and ganglia in males; reproductive problems in females during pregnancy, childbearing, and the period immediately after delivery (puerperium); tumor increases (malignant in females, benign in males); hematological alterations; and effects on mood and well-being including irritability, depression, loss of appetite, concentration, and eye problems. This description of symptoms in the early literature is nearly identical to the Santini, Abdel-Rassoul, and Narvarro studies cited earlier, as well as the current (though still anecdotal) reports in communities where broadcast facilities have switched from analog to digital signals at power intensities that are remarkably similar. In addition, the symptoms in the older literature are also quite similar to complaints in people with EHS.

Such reports of adverse effects on well-being are occurring worldwide near cell infrastructure and this does not appear to be related to emotional perceptions of risk. Similar symptoms have also been recorded at varying distances from broadcast towers. It is clear that something else is going on in populations exposed to low-level RFR that computer-generated RFR propagation models and obsolete exposure standards, which only protect against acute exposures, do not encompass or understand. With the increase in so many RFR-emitting devices today, as well as the many in the wings that will dramatically increase total exposures to the population from infrastructure alone, it may be time to approach this from a completely different perspective.

It might be more realistic to consider ambient outdoor and indoor RFR exposures in the same way we consider other environmental hazards such as chemicals from building materials that cause sick building syndrome. In considering public health, we should concentrate on aggregate exposures from multiple sources, rather than continuing to focus on individual source points like cell and broadcast base stations. In addition, whole categorically excluded technologies must be included for systems like Wi-Fi, Wi-Max, smart grids, and smart metering as these can greatly increase ambient radiation levels. Only in that way will low-level electromagnetic energy exposures be understood as the broad environmental factor it is. Radiofrequency radiation is a

form of energetic air pollution and it should be controlled as such. Our current predilection to take this one product or service at a time does not encompass what we already know beyond reasonable doubt. Only when aggregate exposures are better understood by consumers will disproportionate resistance to base station siting bring more intelligent debate into the public arena and help create safer infrastructure. That can also benefit the industries trying to satisfy customers who want such services.

Safety to populations living or working near communications infrastructure has not been given the kind of attention it deserves. Aggregate ambient outdoor and indoor exposures should be emphasized by summing up levels from different generating source points in the vicinity. Radiofrequency radiation should be treated and regulated like radon and toxic chemicals, as aggregate exposures, with appropriate recommendations made to the public including for consumer products that may produce significant RFR levels indoors. When indoor consumer products such as wireless routers, cordless/DECT phones, leaking microwave ovens, wireless speakers, and (or) security systems, etc. are factored in with nearby outdoor transmission infrastructure, indoor levels may rise to exposures that are unsafe. The contradictions in the studies should not be used to paralyze movement toward safer regulation of consumer products, new infrastructure creation, or better tower siting. Enough good science exists regarding long-term low-level exposures — the most prevalent today — to warrant caution.

The present U.S. guidelines for RFR exposure are not up to date. The most recent IEEE and NCRP guidelines used by the U.S. FCC have not taken many pertinent recent studies into consideration because, they argue, the results of many of those studies have not been replicated and thus are not valid for standards setting. That is a specious argument. It implies that someone tried to replicate certain works but failed to do so, indicating the studies in question are unreliable. However, in most cases, no one has tried to exactly replicate the works at all. It must be pointed out that the 4 W/kg SAR threshold based on the de Lorge studies have also not been replicated independently. In addition, effects of long-term exposure, modulation, and other propagation characteristics are not considered. Therefore, the current guidelines are questionable in protecting the public from possible harmful effects of RFR exposure and the U.S. FCC should take steps to update their regulations by taking all recent research into consideration without waiting for replication that may never come because of the scarcity of research funding. The ICNIRP standards are more lenient in key exposures to the population than current U.S. FCC regulations. The U.S. standards should not be "harmonized" toward more lenient allowances. The ICNIRP should become more protective instead. All standards should be biologically based, not dosimetry based as is the case today.

Exposure of the general population to RFR from wireless communication devices and transmission towers should be kept to a minimum and should follow the "As Low As Reasonably Achievable" (ALARA) principle. Some scientists, organizations, and local governments recommend very low exposure levels — so low, in fact, that many wireless industries claim they cannot function without many more antennas in a given area. However, a denser infrastructure may be impossible to attain because of citizen unwillingness to live in proximity to so many antennas. In general, the lowest regulatory standards currently in place aim to accomplish a maximum exposure of 0.02 V/m, equal to a power density of 0.0001 μW/cm^2, which is in line with Salzburg, Austria's indoor exposure value for GSM cell base stations. Other precautionary target levels aim for an outdoor cumulative exposure of 0.1 μW/cm^2 for pulsed RF exposures where they affect the general population and an indoor exposure as low as 0.01 μW/cm^2 (Sage and Carpenter 2009). In 2007, *The BioInitiative Report, A rationale for a biologically based public exposure standard for electromagnetic fields (ELF and RF)*, also made this recommendation, based on the precautionary principle (Bioinitiative Report 2007).

Citizens and municipalities often ask for firm setbacks from towers to guarantee safety. There are many variables involved with safer tower siting — such as how many providers are co-located, at what frequencies they operate, the tower's height, surrounding topographical characteristics, the presence of metal objects, and others. Hard and fast setbacks are difficult to recommend in all circumstances. Deployment of base stations should be kept as efficient as possible to avoid exposure of the public to unnecessary high levels of RFR. As a general guideline, cell base stations should not be located less than 1500 ft (~500 m) from the population, and at a height of about 150 ft (~50 m). Several of the papers previously cited indicate that symptoms lessen at that distance, despite the many variables involved. However, with new technologies now being added to cell towers such as Wi-Max networks, which add significantly more power density to the environment, setback recommendations can be a very unpredictable reassurance at best. New technology should be developed to reduce the energy required for effective wireless communication.

In addition, regular RFR monitoring of base stations should be considered. Some communities require that ambient background levels be measured at specific distances from proposed tower sites before, and after, towers go online to establish baseline data in case adverse effects in the population are later reported. The establishment of such baselines would help epidemiologists determine what changed in the environment at a specific point in time and help better assess if RFR played a role in health effects. Unfortunately, with so much background RFR today, it is almost impossible to find a clean RFR environment. Pretesting may have become impossible in many places. This will certainly be the case when smart grid technologies create a whole new blanket of low-level RFR, with millions of new transceivers attached to people's homes and appliances, working off of centralized RFR hubs in every neighborhood. That one technology alone has the ability to permanently negate certain baseline data points.

The increasing popularity of wireless technologies makes understanding actual environmental exposures more critical with each passing day. This also includes any potential effects on wildlife. There is a new environmental concept taking form — that of "air as habitat" (Manville 2007) for species such as birds, bats, and insects, in the same way that water is considered habitat for marine life. Until now, air has been considered something "used" but not necessarily "lived in" or critical to the survival of species. How-

ever, when air is considered habitat, RFR is among the potential pollutants with an ability to adversely affect other species. It is a new area of inquiry deserving of immediate funding and research.

References

Abdel-Rassoul, G., El-Fateh, O.A., Salem, M.A., Micgael, A., Farahat, F., and Salem, E. 2007. Neurobehavioral effects among inhabitants around mobile phone base stations. Neurotoxicology, **28**(2): 434–440. doi:10.1016/j.neuro.2006.07.012.

Altpeter, E., Battaglia, M., Bader, A., Pfluger, D., Minder, C.E., and Abelin, T. 2000. Ten years experience with epidemiological research in the vicinity of short-wave broadcasting area Schwarzenburg; what does the story tell us? *In* Proceedings of the International Conference on Cell Tower Siting, Salzburg, Austria. 7–8 June 2000, *Edited by* Gerd Oberfeld, Printing Office, State of Salzburg, Austria, August 2000. pp. 127–132.

Amoako, J.K., Fletcher, J.J., and Darko, E.O. 2009. Measurement and analysis of radiofrequency radiations from some mobile phone base stations in Ghana. Radiat. Prot. Dosimetry, **135**(4): 256–260. doi:10.1093/rpd/ncp115.

Anglesio, L., Benedetto, A., Bonino, A., Colla, D., Martire, F., Saudino Fusette, S., and d'Amore, G. 2001. Population exposure to electromagnetic fields generated by radio base stations: evaluation of the urban background by using provisional model and instrumental measurements. Radiat. Prot. Dosimetry, **97**: 355–358. PMID:11878419.

Arber, S.L., and Lin, J.C. 1985. Microwave-induced changes in nerve cells: effects of modulation and temperature. Bioelectromagnetics, **6**(3): 257–270. doi:10.1002/bem.2250060306.

Augner, C., Florian, M., Pauser, G., Oberfeld, G., and Hacker, G.W. 2009. GSM base stations: Short-term effects on well-being. Bioelectromagnetics, **30**(1): 73–80. doi:10.1002/bem.20447.

Balmori, A. 2010. Mobile phone mast effects on common frog (*Rana temporaria*) tadpoles: the city turned into a laboratory. Electromagn. Biol. Med. **29**(1–2): 31–35. doi:10.3109/15368371003685363.

Baranski, S. 1972. Histological and histochemical effects of microwave irradiation on the central nervous system of rabbits and guinea pigs. Am. J. Phys. Med. **51**: 182–190. PMID:5052845.

Belyaev, I.Y., Hillert, L., Protopopova, M., Tamm, C., Malmgren, L.O., Persson, B.R., Selivanova, G., and Harms-Ringdahl, M. 2005. 915 MHz microwaves and 50 Hz magnetic field affect chromatin conformation and 53BP1 foci in human lymphocytes from hypersensitive and healthy persons. Bioelectromagnetics, **26**(3): 173–184. doi:10.1002/bem.20103.

Belyaev, I.Y., Markovà, E., Hillert, L., Malmgren, L.O., and Persson, B.R. 2009. Microwaves from UMTS/GSM mobile phones induce long-lasting inhibition of 53BP1/gamma-H2AX DNA repair foci in human lymphocytes. Bioelectromagnetics, **30**(2): 129–141. doi:10.1002/bem.20445.

Biointiative Report. 2007. The BioInitiative Report, A rationale for a biologically-based public exposure standard for electromagnetic fields (ELF and RF). Volume 1, page 31–33. Available from, http://www.BioInitiative.org. (accessed October 2010).

Blackman, C.F., Benane, S.G., Joines, W.T., Hollis, M.A., and House, D.E. 1980. Calcium-ion efflux from brain tissue: power-density versus internal field-intensity dependencies at 50 MHz RF radiation. Bioelectromagnetics, **1**(3): 277–283. doi:10.1002/bem.2250010304.

Blettner, M., Schlehofer, B., Brekenkamp, J., Kowall, B., Schmiedel, S., Reis, U., Potthoff, P., Schüz, J., and Berg-Beckhoff, G. 2009. Mobile phone base stations and adverse health effects: phase 1: A population-based cross-sectional study in Germany. Occup. Environ. Med. **66**(2): 118–123. doi:10.1136/oem.2007.037721.

Bornkessel, C., Schubert, M., Wuschek, M., and Schmidt, P. 2007. Determiniation of the general public exposure around GSM and UMTS base stations. Radiat. Prot. Dosimetry, **124**(1): 40–47. doi:10.1093/rpd/ncm373.

Boscol, P., Di Sciascio, M.B., D'Ostilio, S., Del Signore, A., Reale, M., Conti, P., Bavazzano, P., Paganelli, R., and Di Gioacchino, M. 2001. Effects of electromagnetic fields produced by radio and television broadcasting stations on the immune system of women. Sci. Total Environ. **273**(1–3): 1–10. doi:10.1016/S0048-9697(01)00815-4.

Campisi, A., Gulino, M., Acquaviva, R., Bellia, P., Raciti, G., Grasso, R., Musumeci, F., Vanella, A., and Triglia, A. 2010. Reactive oxygen species levels and DNA fragmentation on astrocytes in primary culture after acute exposure to low intensity microwave electromagnetic field. Neurosci. Lett. **473**(1): 52–55. doi:10.1016/j.neulet.2010.02.018.

Capri, M., Scarcella, E., Fumelli, C., Bianchi, E., Salvioli, S., Mesirca, P., Agostini, C., Antolini, A., Schiavoni, A., Castellani, G., Bersani, F., and Franceschi, C. 2004. In vitro exposure of human lymphocytes to 900 MHz CW and GSM modulated radiofrequency: studies of proliferation, apoptosis and mitochondrial membrane potential. Radiat. Res. **162**(2): 211–218. doi:10.1667/RR3209.

Chiang, H., Yao, G.D., Fang, Q.S., Wang, K.Q., Lu, D.Z., and Zhou, Y.K. 1989. Health effects of environmental electromagnetic fields. J. Bioelectr. **8**: 127–131. doi:10.3109/15368378909020950.

Christ, A., Gosselin, M.C., Christopoulou, M., Kuhn, S., and Kuster, N. 2010. Age-dependent tissue-specific exposure of cell phone users. Phys. Med. Biol. **55**(7): 1767–1783. doi:10.1088/0031-9155/55/7/001.

Cleveland, R.F. 2001. Human exposure to radiofrequency electromagnetic fields: FCC guidelines; global standards; evaluating compliance; federal and local jurisdiction. *In* Cell Towers, Wireless Convenience? or Environmental Hazard? Proceedings of the Cell Towers Forum, State of the Science/State of the Law. *Edited by* B.B. Levitt. Safe Goods/New Century. pp. 116–128.

Colorado Department of Public Health and Environment. 2004. Update: tumor incidence in residents adjacent to the Lookout Mountain Antenna Farm 1979–2002, Colorado Department of Public Health and Environment Report, July 2004.

Cooper, T.G., Mann, S.M., Khalid, M., and Blackwell, R.P. 2006. Public exposure to radio waves near GSM microcell and picocell base stations. J. Radiol. **26**: 199–211.

d'Ambrosio, G., Massa, R., Scarfi, M.R., and Zeni, O. 2002. Cytogenetic damage in human lymphocytes following GMSK phase modulated microwave exposure. Bioelectromagnetics, **23**(1): 7–13. doi:10.1002/bem.93.

D'Andrea, J.A., DeWitt, J.R., Emmerson, R.Y., Bailey, C., Stensaas, S., and Gandhi, O.P. 1986*a*. Intermittent exposure of rats to 2450 MHz microwaves at 2.5 mW/cm^2: behavioral and physiological effects. Bioelectromagnetics, **7**(3): 315–328. doi:10.1002/bem.2250070308.

D'Andrea, J.A., DeWitt, J.R., Gandhi, O.P., Stensaas, S., Lords, J.L., and Nielson, H.C. 1986*b*. Behavioral and physiological effects of chronic 2450 MHz microwave irradiation of the rat at 0.5 mW/cm^2. Bioelectromagnetics, **7**(1): 45–56. doi:10.1002/bem.2250070106.

D'Inzeo, G., Bernardi, P., Eusebi, F., Grassi, F., Tamburello, C., and Zani, B.M. 1988. Microwave effects on acetylcholine-in-

duced channels in cultured chick myotubes. Bioelectromagnetics, **9**(4): 363–372. doi:10.1002/bem.2250090406.

de Lorge, J.O. 1984. Operant behavior and colonic temperature of *Macaca mulatta* exposed to radiofrequency fields at and above resonant frequencies. Bioelectromagnetics, **5**(2): 233–246. doi:10.1002/bem.2250050211.

de Lorge, J., and Ezell, C.S. 1980. Observing-responses of rats exposed to 1.28- and 5.62-GHz microwaves. Bioelectromagnetics, **1**(2): 183–198. doi:10.1002/bem.2250010208.

de Pomerai, D.I., Smith, B., Dawe, A., North, K., Smith, T., Archer, D.B., Duce, I.R., Jones, D., and Candido, E.P. 2003. Microwave radiation can alter protein conformation without bulk heating. FEBS Lett. **543**(1-3): 93–97. doi:10.1016/S0014-5793(03)00413-7.

Department of Health and Human Services. 2008. Statistics, wireless substitution: early release of estimates from the National Health Interview Survey. Centers for Disease Control and Prevention, National Center for Health , July–December 2008. Available from http://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless200905.htm [accessed October 2010].

DeWitt, J.R., D'Andrea, J.A., Emmerson, R.Y., and Gandhi, O.P. 1987. Behavioral effects of chronic exposure to 0.5 mW/cm^2 of 2450-MHz microwaves. Bioelectromagnetics, **8**(2): 149–157. doi:10.1002/bem.2250080205.

Dolk, H., Shaddick, G., Walls, P., Grundy, C., Thakrar, B., Kleinschmidt, I., and Elliott, P. 1997a. Cancer incidence near radio and television transmitters in Great Britain, Part I. Sulton Coldfield Transmitter. Am. J. Epidemiol. **145**: 1–9. PMID: 9440406.

Dolk, H., Elliott, P., Shaddick, G., Walls, P., and Thakrar, B. 1997b. Cancer incidence near radio and television transmitters in Great Britain, Part II. Am. J. Epidemiol. **145**: 10–17. PMID: 8982017.

Dumansky, J.D., and Shandala, M.G. 1974. The biologic action and hygienic significance of electromagnetic fields of super high and ultra high frequencies in densely populated areas. *In* Biologic Effects and Health Hazards of Microwave Radiation: Proceedings of an International Symposium. *Edited by* P. Czerski, et al. Polish Medical Publishers, Warsaw.

Dutta, S.K., Subramoniam, A., Ghosh, B., and Parshad, R. 1984. Microwave radiation-induced calcium ion efflux from human neuroblastoma cells in culture. Bioelectromagnetics, **5**(1): 71–78. doi:10.1002/bem.2250050108.

Dutta, S.K., Ghosh, B., and Blackman, C.F. 1989. Radiofrequency radiation-induced calcium ion efflux enhancement from human and other neuroblastoma cells in culture. Bioelectromagnetics, **10**(2): 197–202. doi:10.1002/bem.2250100208.

Eger, H., Hagen, K.U., Lucas, B., Vogel, P., and Voit, H. 2004. The influence of being physically near to a cell phone transmission mast on the incidence of cancer. Published in Umwelt·Medizin·Gesellschaft 17 April 2004, as: 'Einfluss der räumlichen Nähe von Mobilfunksendeanlagen auf die Krebsinzidenz'. English translation: 8 October 2004, available at http://www.tetrawatch.net/papers/naila.pdf (Accessed October 2010)

Eltiti, S., Wallace, D., Ridgewell, A., Zougkou, K., Russo, R., Sepulveda, F., Mirshekar-Syahkal, D., Rasor, P., Deeble, R., and Fox, E. 2007. Does short-term exposure to mobile phone base station signals increase symptoms in individuals who report sensitivity to electromagnetic fields? A double-blind randomized provocation study. Environ. Health Perspect. **115**(11): 1603–1608. doi:10.1289/ehp.10286.

Eltiti, S., Wallace, D., Ridgewell, A., Zougkou, K., Russo, R., Sepulveda, F., and Fox, E. 2009. Short-term exposure to mobile phone base station signals does not affect cognitive functioning or physiological measures in individuals who report sensitivity to electromagnetic fields and controls. Bioelectromagnetics, **30**(7): 556–563. doi:10.1002/bem.20504.

Fesenko, E.E., Makar, V.R., Novoselova, E.G., and Sadovnikov, V.B. 1999. Microwaves and cellular immunity. I. Effect of whole body microwave irradiation on tumor necrosis factor production in mouse cells. Bioelectrochem. Bioenerg. **49**(1): 29–35. doi:10.1016/S0302-4598(99)00058-6.

Forgacs, Z., Somosy, Z., Kubinyi, G., Bakos, J., Hudak, A., Surjan, A., and Thuroczy, G. 2006. Effect of whole-body 1800MHz GSM-like microwave exposure on testicular steroidogenesis and histology in mice. Reprod. Toxicol. **22**(1): 111–117. doi:10.1016/j.reprotox.2005.12.003.

Frei, P., Mohler, E., Neubauer, G., Theis, G., Bürgi, A., Fröhlich, J., Braun-Fahrländer, C., Bolte, J., Egger, M., and Röösli, M. 2009. Temporal and spatial variability of personal exposure to radio frequency electromagnetic fields. Environ. Res. **109**(6): 779–785. doi:10.1016/j.envres.2009.04.015.

Frey, A.H., Feld, S.R., and Frey, B. 1975. Neural function and behavior: defining the relationship. Ann. N. Y. Acad. Sci. **247**(1 Biologic Effe): 433–439. doi:10.1111/j.1749-6632.1975.tb36019.x.

Furubayashi, T., Ushiyama, A., Terao, Y., Mizuno, Y., Shirasawa, K., Pongpaibool, P., Simba, A.Y., Wake, K., Nishikawa, M., Miyawaki, K., Yasuda, A., Uchiyama, M., Yamashita, H.K., Masuda, H., Hirota, S., Takahashi, M., Okano, T., Inomata-Terada, S., Sokejima, S., Maruyama, E., Watanabe, S., Taki, M., Ohkubo, C., and Ugawa, Y. 2009. Effects of short-term W-CDMA mobile phone base station exposure on women with or without mobile phone related symptoms. Bioelectromagnetics, **30**(2): 100–113. doi:10.1002/bem.20446.

Gage, M.I. 1979. Behavior in rats after exposure to various power densities of 2450 MHz microwaves. Neurobehav. Toxicol. **1**: 137–143.

Gandhi, O., Lazzi, P.G., and Furse, C.M. 1996. Electromagnetic absorption in the head and neck for mobile telephones at 835 and 1900 MHz. IEEE Trans. Microw. Theory Tech. **44**(10): 1884–1897. doi:10.1109/22.539947.

Guler, G., Tomruk, A., Ozgur, E., and Seyhan, N. 2010. The effect of radiofrequency radiation on DNA and lipid damage in non-pregnant and pregnant rabbits and their newborns. Gen. Physiol. Biophys. **29**(1): 59–66. doi:10.4149/gpb_2010_01_59.

Ha, M., Lim, H.J., Cho, S.H., Choi, H.D., and Cho, K.Y. 2003. Incidence of cancer in the vicinity of Korean AM radio transmitters. Arch. Environ. Health, **58**(12): 756–762. doi:10.3200/AEOH.58.12.756-762.

Ha, M., Im, H., Lee, M., Kim, H.J., Kim, B.C., Gimm, Y.M., and Pack, J.K. 2007. Radio-frequency radiation exposure from AM radio transmitters and childhood leukemia and brain cancer. Am. J. Epidemiol. **166**(3): 270–279. doi:10.1093/aje/kwm083.

Hallberg, O., and Johansson, O. 2002. Melanoma incidence and frequency modulation (FM) broadcasting. Arch. Environ. Health, **57**(1): 32–40. doi:10.1080/00039890209602914.

Hansson Mild, K., Repacholi, M., van Deventer, E., and Ravazzani, P. (*Editors*). 2006. Working Group Report. *In* Proceedings International Workshop on EMF Hypersensitivity 25–27 October 2004, Prague, Czech Republic. MilanL WHO Press. pp. 15–6. Available from: www.who.int/peh-emf/meetings/hypersensitivity_prague2004/en/index.html. [Accessed May 2007.]

Henderson, A., and Anderson, B.S. 1986. Cancer incidence in census tracts with broadcast towers in Honolulu, Hawaii. Report prepared by Environmental Epidemiology Program, State of Hawaii, Department of Public Health, 27 October 1986.

Henderson, S.I., and Bangay, M.J. 2006. Survey of RF exposure levels from mobile telephone base stations in Australia. Bioelectromagnetics, **27**(1): 73–76. doi:10.1002/bem.20174.

Hjollund, N.H., Bonde, J.P., and Skotte, J. 1997. Semen analysis of personnel operating military radar equipment. Reprod. Toxicol. **11**(6): 897. doi:10.1016/S0890-6238(97)00074-9. PMID: 9407601.

Hocking, B., Gordon, I.R., Grain, H.L., and Hatfield, G.E. 1996. Cancer incidence and mortality and proximity to TV towers. Med. J. Aust. **165**: 601–605. PMID:8985435.

Huber, R., Treyer, V., Borbély, A.A., Schuderer, J., Gottselig, J.M., Landolt, H.-P., Werth, E., Berthold, T., Kuster, N., Buck, A., and Achermann, P. 2002. Electromagnetic fields, such as those from mobile phones, alter regional cerebral blood flow and sleep and waking EEG. J. Sleep Res. **11**(4): 289–295. doi:10.1046/j.1365-2869.2002.00314.x.

Hung, C.S., Anderson, C., Horne, J.A., and McEvoy, P. 2007. Mobile phone 'talk-mode' signal delays EEG-determined sleep onset. Neurosci. Lett. **421**(1): 82–86. doi:10.1016/j.neulet.2007.05.027.

Hutter, H.-P., Moshammer, H., Wallner, P., and Kundi, M. 2006. Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations. Occup. Environ. Med. **63**(5): 307–313. doi:10.1136/oem.2005.020784.

ICNIRP. 1998. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields. International Council on Non-Ionizing Radiation (ICNIRP). Oberschleisseim, Germany 1998. www.icnirp.org/documents/emfgdl.pdf. (Accessed October 2010.)

Ivaschuk, O.I., Jones, R.A., Ishida-Jones, T., Haggren, W., Adey, W.R., and Phillips, J.L. 1997. Exposure of nerve growth factor-treated PC12 rat pheochromocytoma cells to a modulated radiofrequency field at 836.55 MHz: effects on c-jun and c-fos expression. Bioelectromagnetics, **18**(3): 223–229. doi:10.1002/(SICI)1521-186X(1997)18:3<223::AID-BEM4>3.0.CO;2-4.

Jech, R., Sonka, K., Ruzicka, E., Nebuzelsky, A., Bohm, J., Juklickova, M., and Nevsimalova, S. 2001. Electromagnetic field of mobile phones affects visual event related potential in patients with narcolepsy. Bioelectromagnetics, **22**: 519–528. doi:10.1002/bem.81.

Johnson, R.B., Spackman, D., Crowley, J., Thompson, D., Chou, C.K., Kunz, L.L., and Guy, A.W. 1983. Effects of long-term low-level radiofrequency radiation exposure on rats, Vol. 4, Open field behavior and corticosterone, USAF SAM-TR83-42, Report of U.S. Air Force (USAF) School of Aerospace Medicine, Brooks City Air Force Base, San Antonio, Tex.

Johnson-Liakouris, A.J. 1998. Radiofrequency (RF) sickness in the Lilienfeild Study; an effect of modulated microwaves? Arch. Environ. Health, **53**: 236–238. PMID:9814721.

Joseph, W., Vermeeren, G., Verloock, L., and Martens, L. 2010. Estimation of whole-body SAR from electromagnetic fields using personal exposure meters. Bioelectromagnetics, **31**: 286–295.

Kesari, K.K., and Behari, J. 2009. Fifty-gigahertz microwave exposure effect of radiations on rat brain. Appl. Biochem. Biotechnol. **158**(1): 126–139. doi:10.1007/s12010-008-8469-8.

Kesari, K.K., and Behari, J. 2010. Microwave exposure affecting reproductive system in male rats. Appl. Biochem. Biotechnol. **162**(2): 416–428. doi:10.1007/s12010-009-8722-9.

Kesari, K.K., Behari, J., and Kumar, S. 2010. Mutagenic response of 2.45 GHz radiation exposure on rat brain. Int. J. Radiat. Biol. **86**(4): 334–343. doi:10.3109/09553000903564059.

King, N.W., Justesen, D.R., and Clarke, R.L. 1971. Behavioral sensitivity to microwave irradiation. Science, **172**(3981): 398–401. doi:10.1126/science.172.3981.398.

Kolodynski, A., and Kolodynski, V. 1996. Motor and psychological functions of school children living in the area of the Skundra Radio Location Station in Latvia. Sci. Total Environ. **180**(1): 87–93. doi:10.1016/0048-9697(95)04924-X.

Kristiansen, I.S., Elstein, A.S., Gyrd-Hansen, D., Kildemoes, H.W., and Nielsen, J.B. 2009. Radiation from mobile phone systems: Is it perceived as a threat to people's health? Bioelectromagnetics, **30**(5): 393–401. doi:10.1002/bem.20484.

Kumlin, T., Iivonen, H., Miettinen, P., Juvonen, A., van Groen, T., Puranen, L., Pitkäaho, R., Juutilainen, J., and Tanila, H. 2007. Mobile phone radiation and the developing brain: behavioral and morphological effects in juvenile rats. Radiat. Res. **168**(4): 471–479. doi:10.1667/RR1002.1.

Kwee, S., Raskmark, P., and Velizarov, P. 2001. Changes in cellular proteins due to environmental non-ionizing radiation. I. Heat-shock proteins. Electro- Magnetobiol. **20**: 141–152. doi:10.1667/RR1002.1.

Lai, H., Horita, A., Chou, C.K., and Guy, A.W. 1987. Effects of low-level microwave irradiation on hippocampal and frontal cortical choline uptake are classically conditionable. Pharmacol. Biochem. Behav. **27**(4): 635–639. doi:10.1016/0091-3057(87)90186-9.

Lai, H., Carino, M.A., Horita, A. and Guy, A.W. 1992. Single vs. repeated microwave exposure: effects on benzodiazepine receptors in the brain of the rat. Bioelectromagnetics **13**:57–66. PMID:1312845.

Lai, H., Carino, M.A., Horita, A. and Guy, A.W. 1989. Low-level microwave irradiation and central cholinergic systems. Pharmacol. Biochem. Behav. **33**(1): 131–138. doi:10.1016/0091-3057(89)90442-5.

Lebedeva, N.N., Sulimov, A.V., Sulimova, O.P., Kotrovskaya, T.I., and Gailus, T. 2000. Cellular phone electromagnetic field effects on bioelectric activity of human brain. Crit. Rev. Biomed. Eng. **28**: 323–337. PMID: 10999398.

Lerchl, A., Krüger, H., Niehaus, M., Streckert, J.R., Bitz, A.K., and Hansen, V. 2008. Effects of mobile phone electromagnetic fields at nonthermal SAR values on melatonin and body weight of Djungarian hamsters (*Phodopus sungorus*). J. Pineal Res. **44**(3): 267–272. doi:10.1111/j.1600-079X.2007.00522.x.

Levitt, B.B, Electromagnetic fields, A consumer's guide to the issues and how to protect ourselves, Harcourt Brace & Co., San Diego, New York, London, 1995, p. 23.

Levitt, B.B., Cell-phone towers and communities, The struggle for local control. Orion Afield, Publisher, The Orion Society, Great Barrington, Mass. Autumn 1998, pp. 32–36.

Lilienfield, A.M., Libauer, G.M., Cauthen, J., Tonascia, S., and Tonascia, J. 1978. Evaluation of health status of foreign service and other employees from selected eastern European embassies. Foreign Service Health Status Study, Final Report; Contract No. 6025-619037 (NTIS publication P8-288 163/9) Washington, D.C.; National Technical Information Service, U.S. Department of Commerce.

Luukkonen, J., Hakulinen, P., Mäki-Paakkanen, J., Juutilainen, J., and Naarala, J. 2009. Enhancement of chemically induced reactive oxygen species production and DNA damage in human SH-SY5Y neuroblastoma cells by 872 MHz radiofrequency radiation. Mutat. Res. **662**: 54–58. PMID:19135463.

Magras, I.N., and Xenos, T.D. 1997. RF radiation-induced changes in the prenatal development of mice. Bioelectromagnetics, **18**(6): 455–461. doi:10.1002/(SICI)1521-186X(1997)18:6<455::AID-BEM8>3.0.CO;2-1.

Mann, K., Wagner, P., Brunn, G., Hassan, F., Hiemke, C., and

Roschke, J. 1998. Effects of pulsed high-frequency electromagnetic fields on the neuroendocrine system. Neuroendocrinology, **67**: 139–144. doi:10.1159/000054308.

Mann, S.M., Cooper, T.G., Allen, S.G., Blackwell, R.P., and Lowe, A.J. 2002. Exposures to radio waves near mobile phone base stations. Chilton. National Radiological Protection Board, NRPB-R321. Available from: www.hpa.org.uk/radiation/publications/archive/reports/2000/nrpb_r321. (Accessed October 2010.)

Manville, A., III. 2007. Briefing paper on the need for research into the cumulative impacts of communication towers on migratory birds and other wildlife in the United States. Communication Tower Research Needs - Public Briefing-2-807.doc, Division of Migratory Bird Management (DMBM), U.S. Fish & Wildlife Service, updated 13 August 2007.

Marinelli, F., La Sala, D., Cicciotti, G., Cattini, L., Trimarchi, C., Putti, S., Zamparelli, A., Giuliani, L., Tomassetti, G., and Cinti, C. 2004. Exposure to 900 MHz electromagnetic field induces an unbalance between pro-apoptotic and pro-survival signals in T-lymphoblastoid leukemia CCRF–CEM cells. J. Cell. Physiol. **198**(2): 324–332. doi:10.1002/jcp.10425.

Markkanen, A., Penttinen, P., Naarala, J., Pelkonen, J., Sihvonen, A.P., and Juutilainen, J. 2004. Apoptosis induced by ultraviolet radiation is enhanced by amplitude modulated radiofrequency radiation in mutant yeast cells. Bioelectromagnetics, **25**(2): 127–133. doi:10.1002/bem.10167.

Markovà, E., Hillert, L., Malmgren, L., Persson, B.R., and Belyaev, I.Y. 2005. Microwaves from GSM mobile telephones affect 53BP1 and gamma-H2AX foci in human lymphocytes from hypersensitive and healthy persons. Environ. Health Perspect. **113**(9): 1172–1177. doi:10.1289/ehp.7561.

Martínez-Búrdalo, M., Martín, A., Anguiano, M., and Villar, R. 2005. On the safety assessment of human exposure in the proximity of cellular communications base-station antennas at 900, 1800 and 2170 MHz. Phys. Med. Biol. **50**(17): 4125–4137. doi:10.1088/0031-9155/50/17/015.

Maskarinec, G., Cooper, J., and Swygert, I. 1994. Investigation of increased incidence in childhood leukemia near radio towers in Hawaii: preliminary observations. J. Environ. Pathol. Toxicol. Oncol. **13**: 33–37. PMID:7823291.

Michelozzi, P., Capon, A., Kirchmayer, U., Forastiere, F., Biggeri, A., Barca, A., and Perucci, C.A. 2002. Adult and childhood leukemia near a high-power radio station in Rome, Italy. Am. J. Epidemiol. **155**(12): 1096–1103. doi:10.1093/aje/155.12.1096.

Mitchell, D.S., Switzer, W.G., and Bronaugh, E.L. 1977. Hyperactivity and disruption of operant behavior in rats after multiple exposure to microwave radiation. Radio Sci. **12**(6S): 263–271. doi:10.1029/RS012i06Sp00263.

NCRP. 1986. Biological effects and exposure criteria for radiofrequency electromagnetic fields. National Council on Radiation Protection and Measurements. NCRP Report No. 86, 2 April 1986.

Navakatikian, M.A., and Tomashevskaya, L.A. 1994. Phasic behavioral and endocrine effects of microwaves of nonthermal intensity. *In* Biological Effects of Electric and Magnetic Fields, Vol. 1. *Edited by* D.O. Carpenter. Academic Press, San Diego, Calif.

Navarro, A.E., Sequra, J., Portolés, M., and Gómez-Perretta de Mateo, C. 2003. The microwave syndrome: a preliminary study in Spain. Electromagn. Biol. Med. **22**(2-3): 161–169. doi:10.1081/JBC-120024625.

Neubauer, G., Feychting, M., Hamnerius, Y., Kheiferts, L., Kuster, N., Ruiz, I., Schüz, J., Überbacher, R., Wiart, J., and Röösli, M. 2007. Feasibility of future epidemiology studies on possible health effects of mobile phone base stations. Bioelectromagnetics, **28**(3): 224–230. doi:10.1002/bem.20298.

Neubauer, G., Cecil, S., Giczi, W., Petric, B., Preiner, P., and Frolich, J. 2008. Final report on the project C2006-07, evaluation of the correlation between RF dosimeter reading and real human exposure, Austrian Research Centres ARC-Report ARC-IT-0218, April 2008.

Nittby, H., Grafström, G., Tian, D.P., Malmgren, L., Brun, A., Persson, B.R., Salford, L.G., and Eberhardt, J. 2008. Cognitive impairment in rats after long-term exposure to GSM-900 mobile phone radiation. Bioelectromagnetics, **29**(3): 219–232. doi:10.1002/bem.20386.

Novoselova, E.G., Fesenko, E.E., Makar, V.R., and Sadovnikov, V.B. 1999. Microwaves and cellular immunity II. Immunostimulating effects of microwaves and naturally occurring antioxidant nutrients. Bioelectrochem. Bioenerg. **49**(1): 37–41. doi:10.1016/S0302-4598(99)00059-8.

Novoselova, E.G., Ogay, V.B., Sorokina, O.V., Glushkova, O.V., Sinotova, O.A., and Fesenko, E.E. 2004. The production of tumor necrosis factor in cells of tumor-bearing mice after total-body microwave irradiation and antioxidant diet. Electromagn. Biol. Med. **23**: 167–180.

Oberfeld, G., Navarro, A.E., Portoles, M., Maestu, C., and Gomez-Perretta, C. 2004. The microwave syndrome – further aspects of a Spanish study. *In* Proceedings of the 3rd International Workshop on Biological Effects of Electromagnetic Fields, Kos, Greece, 4–8 October 2004.

Ofcom. 2008 *The Communications Market Interim Report*, August 2008. Ofcom, London, UK. Available from http://www.ofcom.org.uk/research/cm/cmr08/. (Accessed October 2010.)

Oscar, K.J., and Hawkins, T.D. 1977. Microwave alteration of the blood-brain barrier system of rats. Brain Res. **126**(2): 281–293. doi:10.1016/0006-8993(77)90726-0.

Panagopoulos, D.J., and Margaritis, L.H. 2010*a*. The identification of an intensity 'window' on the bioeffects of mobile telephony radiation. Int. J. Radiat. Biol. **86**(5): 358–366. doi:10.3109/09553000903567979.

Panagopoulos, D.J., and Margaritis, L.H. 2010*b*. The effect of exposure duration on the biological activity of mobile telephony radiation. Mutat. Res. **699**: 17–22.

Panagopoulos, D.J., Chavdoula, E.D., and Margaritis, L.H. 2010. Bioeffects of mobile telephony radiation in relation to its intensity or distance from the antenna. Int. J. Radiat. Biol. **86**(5): 345–357. doi:10.3109/09553000903567961.

Park, S.K., Ha, M., and Im, H.-J. 2004. Ecological study on residences in the vicinity of AM radio broadcasting towers and cancer death: preliminary observations in Korea. Int. Arch. Occup. Environ. Health, **77**(6): 387–394. doi:10.1007/s00420-004-0512-7.

Pavicic, I., and Trosic, I. 2008. Impact of 864 MHz or 935 MHz radiofrequency microwave radiation on the basic growth parameters of V79 cell line. Acta Biol. Hung. **59**(1): 67–76. doi:10.1556/ABiol.59.2008.1.6.

Pérez-Castejón, C., Pérez-Bruzón, R.N., Llorente, M., Pes, N., Lacasa, C., Figols, T., Lahoz, M., Maestú, C., Vera-Gil, A., Del Moral, A., and Azanza, M.J. 2009. Exposure to ELF-pulse modulated X band microwaves increases in vitro human astrocytoma cell proliferation. Histol. Histopathol. **24**: 1551–1561.

Persson, B.R.R., Salford, L.G., and Brun, A. 1997. Blood–brain barrier permeability in rats exposed to electromagnetic fields used in wireless communication. Wirel. Netw. **3**(6): 455–461. doi:10.1023/A:1019150510840.

Phillips, J.L., Ivaschuk, O., Ishida-Jones, T., Jones, R.A., Campbell-Beachler, M., and Haggren, W. 1998. DNA damage in

JA 06286

Molt-4 T-lymphoblastoid cells exposed to cellular telephone radiofrequency fields in vitro. Bioelectrochem. Bioenerg. **45**(1): 103–110. doi:10.1016/S0302-4598(98)00074-9.

Pologea-Moraru, R., Kovacs, E., Iliescu, K.R., Calota, V., and Sajin, G. 2002. The effects of low level microwaves on the fluidity of photoreceptor cell membrane. Bioelectrochemistry, **56**(1–2): 223–225. doi:10.1016/S1567-5394(02)00037-3.

Pyrpasopoulou, A., Kotoula, V., Cheva, A., Hytiroglou, P., Nikolakaki, E., Magras, I.N., Xenos, T.D., Tsiboukis, T.D., and Karkavelas, G. 2004. Bone morphogenetic protein expression in newborn rat kidneys after prenatal exposure to radiofrequency radiation. Bioelectromagnetics, **25**(3): 216–227. doi:10.1002/bem.10185.

Radon, K., Spegel, H., Meyer, N., Klein, J., Brix, J., Wiedenhofer, A., Eder, H., Praml, G., Schulze, A., Ehrenstein, V., von Kries, R., and Nowak, D. 2006. Personal dosimetry of exposure to mobile telephone base stations? An epidemiological feasibility study comparing the Maschek dosimeter prototype and Antennessa SP-090 system. Bioelectromagnetics, **27**(1): 77–81. doi:10.1002/bem.20175.

REFLEX 2004. REFLEX Final Report: Risk evaluation of potential environmental hazards from low frequency electromangetic field exposure using sensitivie in vitro methods, Europena Union, Quality of Life and Management of Living Resources, Contract: QLK4-CT-1999-01574, 1 February 2000 – 31 May 2004 Available at http://www.itis.ethz.ch/downloads/REFLEX_Final%20Report_171104.pdf. (Accessed October 2010.)

Regel, S.J., Negovetic, S., Röösli, M., Berdiñas, V., Schuderer, J., Huss, A., Lott, U., Kuster, N., and Achermann, P. 2006. UMTS base station-like exposure, well-being, and cognitive performance. Environ. Health Perspect. **114**(8): 1270–1275. doi:10.1289/ehp.8934.

Rinebold, J.M. 2001. State centralized siting of telecommunications facilities and cooperative efforts with Connecticut towns. *In* Cell Towers, Wireless Convenience? or Environmental Hazard? *In* Proceedings of the Cell Towers Forum, State of the Science/State of the Law. *Edited by* B.B. Levitt. Safe Goods/New Century, Sheffield, Mass. pp. 129–141.

Roux, D., Vian, A., Girard, S., Bonnet, P., Paladian, F., Davies, E., and Ledoigt, G. 2008*a*. High frequency (900 MHz) low amplitude (5 V m-1) electromagnetic field: a genuine environmental stimulus that affects transcription, translation, calcium and energy charge in tomato. Planta, **227**(4): 883–891. doi:10.1007/s00425-007-0664-2.

Roux, D., Faure, C., Bonnet, P., Girard, S., Ledoigt, G., Davies, E., Gendraud, M., Paladian, F., and Vian, A. 2008*b*. A possible role for extra-cellular ATP in plant responses to high frequency, low-amplitude electromagnetic field. Plant Signal. Behav. **3**: 383–385.

Sage, C., and Carpenter, D.O. 2009. Public health implications of wireless technologies. Pathophysiology, **16**(2-3): 233–246. doi:10.1016/j.pathophys.2009.01.011.

Salford, L.G., Brun, A.R., Eberhardt, J.L., Malmgren, L., and Persson, B.R.R. 2003. Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones. Environ. Health Perspect. **111**(7): 881–883. doi:10.1289/ehp.6039.

Sanders, A.P., Joines, W.T., and Allis, J.W. 1985. Effect of continuous-wave, pulsed, and sinusoidal–amplitude–modulated microwaves on brain energy metabolism. Bioelectromagnetics, **6**(1): 89–97. doi:10.1002/bem.2250060109.

Santini, R., Santini, P., Danze, J.M., Le Ruz, P., and Seigne, M. 2002. Enquête sur la santé de riverains de stations relais de téléphonie mobile : Incidences de la distance et du sexe. Pathol. Biol. **50**: 369–373. doi:10.1016/S0369-8114(02)00311-5.

Sarimov, R., Malmgren, L.O.G., Markova, E., Persson, B.R.R., and Belyaev, I.Y. 2004. Nonthermal GSM microwaves affect chromatin conformation in human lymphocytes similar to heat shock. IEEE Trans. Plasma Sci. **32**(4): 1600–1608. doi:10.1109/TPS.2004.832613.

Schrot, J., Thomas, J.R., and Banvard, R.A. 1980. Modification of the repeated acquisition of response sequences in rats by low-level microwave exposure. Bioelectromagnetics, **1**(1): 89–99. doi:10.1002/bem.2250010109.

Schwartz, J.L., House, D.E., and Mealing, G.A. 1990. Exposure of frog hearts to CW or amplitude-modulated VHF fields: selective efflux of calcium ions at 16 Hz. Bioelectromagnetics, **11**(4): 349–358. doi:10.1002/bem.2250110409.

Schwarz, C., Kratochvil, E., Pilger, A., Kuster, N., Adlkofer, F., and Rüdiger, H.W. 2008. Radiofrequency electromagnetic fields (UMTS, 1,950 MHz) induce genotoxic effects in vitro in human fibroblasts but not in lymphocytes. Int. Arch. Occup. Environ. Health, **81**(6): 755–767. doi:10.1007/s00420-008-0305-5.

SCENIHR. 2009. Health effects of exposure to EMF, European Commission, Health & Consumer Protection DG. Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), 19 January 2009.

Seaman, R.L., and Wachtel, H. 1978. Slow and rapid responses to CW and pulsed microwave radiation by individual Aplysia pacemakers. J. Microw. Power, **13**: 77–86.

Siegrist, M., Earle, T.C., Gutscher, H., and Keller, C. 2005. Perception of mobile phone and base station risks. Risk Anal. **25**(5): 1253–1264. doi:10.1111/j.1539-6924.2005.00672.x.

Silke, T., Heinrich, S., Kuhnlein, A., and Radon, K. 2010. The association between socioeconomic status and exposure to mobile telecommunication networks in children and adolescents. Bioelectromagnetics, **31**: 20–27.

Sirav, B., and Seyhan, N. 2009. Radio frequency radiation (RFR) from TV and radio transmitters at a pilot region in Turkey. Radiat. Prot. Dosimetry, **136**(2): 114–117. doi:10.1093/rpd/ncp152.

Somosy, Z., Thuroczy, G., Kubasova, T., Kovacs, J., and Szabo, L.D. 1991. Effects of modulated and continuous microwave irradiation on the morphology and cell surface negative charge of 3T3 fibroblasts. Scanning Microsc. **5**: 1145–1155.

Stagg, R.B., Thomas, W.J., Jones, R.A., and Adey, W.R. 1997. DNA synthesis and cell proliferation in C6 glioma and primary glial cells exposed to a 836.55 MHz modulated radiofrequency field. Bioelectromagnetics, **18**(3): 230–236. doi:10.1002/(SICI)1521-186X(1997)18:3<230::AID-BEM5>3.0.CO;2-3.

Stankiewicz, W., Dąbrowski, M.P., Kubacki, R., Sobiczewska, E., and Szmigielski, S. 2006. Immunotropic influence of 900 MHz microwave GSM signal on human blood immune cells activated in vitro. Electromagn. Biol. Med. **25**(1): 45–51. doi:10.1080/15368370600572961.

State of Hawaii, 1991. Investigation of Childhood Leukemia on Waianae Coast 1977–1990. Environmental Epidemiology Program. State of Hawaii Department of Health.

Takashima, S., Onaral, B., and Schwan, H.P. 1979. Effects of modulated RF energy on the EEG of mammalian brain. Radiat. Environ. Biophys. **16**(1): 15–27. doi:10.1007/BF01326893.

Tattersall, J.E., Scott, I.R., Wood, S.J., Nettell, J.J., Bevir, M.K., Wang, Z., Somasiri, N.P., and Chen, X. 2001. Effects of low intensity radiofrequency electromagnetic fields on electrical activity in rat hippocampal slices. Brain Res. **904**(1): 43–53. doi:10.1016/S0006-8993(01)02434-9.

Tell, R. 2008. An analysis of radiofrequency fields associated with operation of the Hydro One Smart Meter System, October 28, 2008. Report by Richard A. Tell, Associates, Inc., Colville, Wash., for Hydro One Networks, Inc., Toronto, Ont.

Thomas, J.R., Finch, E.D., Fulk, D.W., and Burch, L.S. 1975. Effects of low level microwave radiation on behavioral baselines. Ann. N. Y. Acad. Sci. **247**(1 Biologic Effe): 425–432. doi:10.1111/j.1749-6632.1975.tb36018.x.

Tolgskaya, M.S., and Gordon, A.V. 1973. Pathological effects of radio waves. Soviet Science Consultants Bureau, New York. pp. 133–137.

United States Senate. 1979. Microwave rrradiation of the U.S. Embassy in Moscow, Committee on Commerce, Science and Transportation. 96th Congress, 1st session, April 1979, pp. 1–23.

U.S. FCC. 1997. Evaluating compliance with FCC-specified guidelines for human exposure to radiofrequency radiation, U.S. Federal Communications Commission. Office of Engineering and Technology, OET Bulletin 65, Edition 97-101, August 1997, Washington, DC. Available from http://www..fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65.pdf. (Accessed October 2010).

van Wyk, M.J., Bingle, M., and Meyer, F.J. 2005. Antenna modeling considerations for accurate SAR calculations in human phantoms in close proximity to GSM cellular base station antennas. Bioelectromagnetics, **26**(6): 502–509. doi:10.1002/bem.20122.

Velizarov, S., Raskmark, P., and Kwee, S. 1999. The effects of radiofrequency fields on cell proliferation are non-thermal. Bioelectrochem. Bioenerg. **48**(1): 177–180. doi:10.1016/S0302-4598(98)00238-4.

Veyret, B., Bouthet, C., Deschaux, P., de Seze, R., Geffard, M., Joussot-Dubien, J., Diraison, M., Moreau, J.M., and Caristan, A. 1991. Antibody responses of mice exposed to low-power microwaves under combined, pulse-and-amplitude modulation. Bioelectromagnetics, **12**(1): 47–56. doi:10.1002/bem.2250120107.

Vian, A., Roux, D., Girard, S., Bonnet, P., Paladian, F., Davies, E., and Ledoigt, G. 2006. Microwave irradiation affects gene expression in plants. Plant Signal. Behav. **1**(2): 67–70.

Viel, J.-F., Clerc, S., Barberra, C., Rymzhanova, R., Moissonnier, M., Hours, M., and Cardis, E. 2009. Residential exposure to radiofrequency fields from mobile-phone base stations, and broadcast transmitters: a population-based survey with personal meter. Occup. Environ. Med. **66**(8): 550–556. doi:10.1136/oem.2008.044180.

Wachtel, H., Seaman, R., and Joines, W. 1975. Effects of low-intensity microwaves on isolated neurons. Ann. N.Y. Acad. Sci. **247**(1 Biologic Effe): 46–62. doi:10.1111/j.1749-6632.1975.tb35982.x.

Wallace, D., Eltiti, S., Ridgewell, A., Garner, K., Russo, R., Sepulveda, F., Walker, S., Quinlan, T., Dudley, S., Maung, S., Deeble, R., and Fox, E. 2010. Do TETRA (Airwave) base station signals have a short-term impact on health and well-being? A randomized double-blind provocation study. Environ. Health Perspect. **118**(6): 735–741. doi:10.1289/ehp.0901416.

Wang, B.M., and Lai, H. 2000. Acute exposure to pulsed 2450-MHz microwaves affects water-maze performance of rats. Bioelectromagnetics, **21**(1): 52–56. doi:10.1002/(SICI)1521-186X(200001)21:1<52::AID-BEM8>3.0.CO;2-6.

Wiart, J., Hadjem, A., Wong, M.F., and Bloch, I. 2008. Analysis of RF exposures in the head tissues of children and adults. Phys. Med. Biol. **53**(13): 3681–3695. doi:10.1088/0031-9155/53/13/019.

Wilén, J., Johansson, A., Kalezic, N., Lyskov, E., and Sandström, M. 2006. Psychophysiological tests and provocation of subjects with mobile phone related symptoms. Bioelectromagnetics, **27**(3): 204–214. doi:10.1002/bem.20195.

Wolf, R., and Wolf, D. 2004. Increased incidence of cancer near a cell-phone transmitter station. Inter. J. Cancer Prev. **1**(2): 123–128.

Wolke, S., Neibig, U., Elsner, R., Gollnick, F., and Meyer, R. 1996. Calcium homeostasis of isolated heart muscle cells exposed to pulsed high-frequency electromagnetic fields. Bioelectromagnetics, **17**(2): 144–153. doi:10.1002/(SICI)1521-186X(1996)17:2<144::AID-BEM9>3.0.CO;2-3.

Yurekli, A.I., Ozkan, M., Kalkan, T., Saybasili, H., Tuncel, H., Atukeren, P., Gumustas, K., and Seker, S. 2006. GSM base station electromagnetic radiation and oxidative stress in rats. Electromagn. Biol. Med. **25**(3): 177–188. doi:10.1080/15368370600875042.

This article has been cited by:

1. Alfonso Balmori. 2015. Anthropogenic radiofrequency electromagnetic fields as an emerging threat to wildlife orientation. *Science of The Total Environment* **518-519**, 58-60. [CrossRef]
2. Levent Seyfi. 2015. Assessment of Electromagnetic Radiation with Respect to Base Station Types. *International Journal of Information and Electronics Engineering* **5**. . [CrossRef]
3. Alfonso Balmori. 2014. Electrosmog and species conservation. *Science of The Total Environment* **496**, 314-316. [CrossRef]
4. Gursatej Gandhi, Gurpreet Kaur, Uzma Nisar. 2014. A cross-sectional case control study on genetic damage in individuals residing in the vicinity of a mobile phone base station. *Electromagnetic Biology and Medicine* 1-11. [CrossRef]
5. Paola A. Mello, Juliano S. Barin, Ricardo A. GuarnieriMicrowave Heating 59-75. [CrossRef]
6. Claudia Roda, Susan Perry. 2013. Mobile phone infrastructure regulation in Europe: Scientific challenges and human rights protection. *Environmental Science & Policy* . [CrossRef]
7. Dimitris J. Panagopoulos. 2012. Effect of Microwave Exposure on the Ovarian Development of Drosophila melanogaster. *Cell Biochemistry and Biophysics* **63**, 121-132. [CrossRef]
8. Lennart Hardell, Michael Carlberg, Kjell Hansson Mild, Mikael Eriksson. 2011. Case-control study on the use of mobile and cordless phones and the risk for malignant melanoma in the head and neck region. *Pathophysiology* **18**, 325-333. [CrossRef]

Cell Towers; Research Summaries of Cell Tower Radiation studies

Research on Cell Tower Radiation

Claudia Roda, Susan Perry. **Mobile phone infrastructure regulation in Europe: Scientific challenges and human rights protection**.Environmental Science & Policy, Volume 37, March 2014, Pages 204-214.

- This law article was published in Environmental Science & Policy by human rights experts. It argues that cell tower placement is a human rights issue for children.
- “We argue that (1) because protection of children is a high threshold norm in Human Right law and (2) the binding language of the Convention on the Rights of the Child obliges States Parties to provide a higher standard of protection for children than adults, any widespread or systematic form of environmental pollution that poses a long-term threat to a child’s rights to life, development or health may constitute an international human rights violation.
- In particular we have explained how the dearth of legislation to regulate the installation of base stations (cell towers) in close proximity to children's facilities and schools clearly constitutes a human rights concern according to the language of the Convention on the Rights of the Child, a treaty that has been ratified by all European States.

SAFETY ZONE DETERMINATION FOR WIRELESS CELLULAR TOWER Nyakyi et al, Tanzania (2013)

- This research looked at the radiation that cell towers emit and states at safety zone is needed around the towers to ensure safe sleeping areas.The authors state that "respective authorities should ensure that people reside far from the tower by 120m or more depending on the power transmitted to avoid severe health effect."

Long-term exposure to microwave radiation provokes cancer growth: evidences from radars and mobile communication systems. Yakymenko , 2011

- We conclude that recent data strongly point to the need for re-elaboration of the current safety limits for non-ionizing radiation using recently obtained knowledge. We also emphasize that the everyday exposure of both occupational and general public to MW radiation should be regulated based on a precautionary principles which imply maximum restriction of excessive exposure.

A cross-sectional case control study on genetic damage in individuals residing in the vicinity of a mobile phone base station. Ghandi et al, 2014 (India):

- This cross-sectional case control study on genetic damage in individuals living near cell towers found genetic damage parameters of DNA were significantly elevated. The authors state, " The genetic damage evident in the participants of this study needs to be addressed against future disease-risk, which in addition to neurodegenerative disorders, may lead to cancer."

Neurobehavioral effects among inhabitants around mobile phone base stations, Neurotoxicology, G. Abdel-Rassoul, et al., (2007)

- "Conclusions and recommendations: Inhabitants living nearby mobile phone base stations are at risk for developing neuropsychiatric problems and some changes in the performance of neurobehavioral functions either by facilitation or inhibition.So, revision of standard guidelines for public exposure to RER from mobile phone base station antennas and using of NBTB for regular assessment and early detection of biological

Mortality by neoplasia and cellular telephone base stations. Dode et al., 2011 (Brazil):

- A clearly elevated relative risk of cancer mortality at residential distances of 500 meters or less from cell phone transmission towers.
- This 10 year study on cell phone antennas was released by the Municipal Health Department in Belo Horizonte and several universities in Brazil. Shortly after this study was published, the city prosecutor sued several cell phone companies and requested that almost half of the cities antennae be removed. Many were.

Carpenter, D. O. **Human disease resulting from exposure to electromagnetic fields,** Reviews on Environmental Health, Volume 28, Issue 4, Pages 159172.

- This review summarizes the evidence stating that excessive exposure to magnetic fields from power lines and other sources of electric current increases the risk of development of some cancers and neurodegenerative diseases, and that excessive exposure to RF radiation increases risk of cancer, male infertility, and neurobehavioral abnormalities.

Shinjyo, T. & Shinjyo, A. (2014), Signifikanter Rückgang klinischer Symptome nach Senderabbau – eine Interventionsstudie. (English-Significant Decrease of Clinical Symptoms after Mobile Phone Base Station Removal – An Intervention Study) Tetsuharu Shinjyo and Akemi Shinjyo
Umwelt-Medizin-Gesellschaft, 27(4), S. 294-301.

- This research was undertaken to investigate the validity of concerns about whether chronic exposure to radiofrequency electromagnetic fields (RF-EMFs) emitted from mobile phone base station antennas could cause adverse health effects. The aim of this study was to identify possible adverse health effects among the residents of a condominium on which a mobile phone base station with sets of antennas operating at two different frequencies had been mounted. This research was conducted without outside funds in order to maintain neutrality and avoid pressures from external sources.

- Methods: We investigated possible adverse effects on the health of condominium inhabitants who were exposed from 1998 to 2009 to the radiation from mobile phone base station antennas installed on top of their condominium. To accomplish this, in January and November 2009, 107 of 122 inhabitants were interviewed and underwent medical examinations. The first examination was carried out while the base station was in operation, the second examination three months after the base station antennas were removed once and for all. Based on the health examination results, the residents' health and its changes during the operation of the antennas and after their removal were compared.

- Results: In several cases, significant effects on the inhabitants' health could be proven. The health of these inhabitants was shown to improve after the removal of the antennas, and the researchers

could identify no other factors that could explain this health improvement. These examinations and interviews suggest that there are possible adverse health effects related to RF-EMF exposure among people living under mobile phone base stations.

- Conclusions and recommendations: The results of these examinations and interviews indicate a connection between adverse health effects and electromagnetic radiation from mobile phone base stations. Further research and studies are recommended regarding the possible adverse health effects of RF-EMFs. These results lead us to question the construction of mobile phone base stations on top of buildings such as condominiums or houses.

Epidemiological Evidence for a Health Risk from Mobile Phone Base Stations Khurana, Hardell et al., Int. J Occup. Envir Health, Vol 16(3):263267, 2010

- 10 epidemiological studies that assessed for putative health effects of mobile phone base stations. Seven of these studies explored the association between base station proximity and neurobehavioral effects and three investigated cancer. We found that eight of the 10 studies reported increased prevalence of adverse neurobehavioral symptoms or cancer in populations living at distances < 500 meters from base stations.
- None of the studies reported exposure above accepted international guidelines, suggesting that current guidelines may be inadequate in protecting the health of human populations. We believe that comprehensive epidemiological studies of long-term mobile phone base station exposure are urgently required to more definitively understand its health impact.

Levitt & Lai,**Biological Effects from Exposure to Electromagnetic Radiation Emitted by Cell Tower Base Stations and Other Antenna Arrays,** Environmental Reviews, 2010

- Over 100 citations, approximately 80% of which showed biological effects near towers. "Both anecdotal reports and some epidemiology studies have found headaches, skin rashes, sleep disturbances, depression, decreased libido, increased rates of suicide, concentration problems, dizziness, memory changes, increased risk of cancer, tremors, and other neurophysiological effects in populations near base stations. Built case for 'setbacks' and need for new exposure guidelines reflecting multiple and cumulative exposures

Effect of GSTM1 and GSTT1 Polymorphisms on Genetic Damage in Humans Populations Exposed to Radiation From Mobile Towers

Gulati S, Yadav A, Kumar N, Kanupriya, Aggarwal NK, Kumar R, Gupta R. **Effect of GSTM1 and GSTT1 Polymorphisms on Genetic Damage in Humans Populations Exposed to Radiation From Mobile Towers.** Arch Environ Contam Toxicol. 2015 Aug 5. [Epub ahead of print]

- In our study, 116 persons exposed to radiation from mobile towers and 106 control subjects were genotyped for polymorphisms in the GSTM1 and GSTT1 genes by multiplex polymerase chain reaction method. DNA damage in peripheral blood lymphocytes was determined using alkaline comet assay in terms of tail moment (TM) value and micronucleus assay in buccal cells (BMN). Our results indicated that TM value and BMN frequency were higher in an exposed population compared with a control group and the difference is significant. In our study, we found that different health symptoms, such as depression, memory status, insomnia, and hair loss, were significantly associated with exposure to EMR. Damaging effects of nonionizing radiation result from the generation of reactive oxygen species (ROS) and subsequent radical formation and from direct damage to cellular macromolecules including DNA.

Hutter HP et al, (May 2006) **Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations,** Occup Environ Med. 2006 May;63(5):307-13

- Found a significant relationship between some cognitive symptoms and measured power density; highest for headaches. Perceptual speed increased, while accuracy decreased insignificantly with increasing exposure levels. There was no significant effect on sleep quality.

Eskander EF et al, (November 2011) **How does long term exposure to base stations and mobile phones affect human hormone profiles?** Clin Biochem. 2011 Nov 27.

- Showed significant decrease in volunteers' ACTH, cortisol, thyroid hormones, prolactin for young females, and testosterone levels from RF exposures from both mobiles and cell towers.

Investigation on the health of people living near mobile telephone relay stations: Incidence according to distance and sex Santini et al, 2002 (France)

- 530 people living near mobile phone masts reported more symptoms of headache, sleep disturbance, discomfort, irritability, depression, memory loss and concentration problems the closer they lived to the mast. This first study on symptoms experienced by people living in vicinity of base stations shows that, in view of radioprotection, minimal distance of people from cellular phone base stations should not be < 300 m.

The Microwave Syndrome: A preliminary Study. Navarro E, 2003 (Spain)

- Statistically significant positive exposure-response associations between field intensity and fatigue, irritability, headaches, nausea, loss of appetite, sleeping disorder, depressive tendency, feeling of discomfort, difficulty in concentration, loss of memory, visual disorder, dizziness and cardiovascular problems. Two different exposure groups also showed an increase of the declared severity in the group with the higher exposure.

Bortkiewicz et al, 2004 (Poland)

- Residents close to mobile phone masts reported: more incidences of circulatory problems, sleep disturbances, irritability, depression, blurred vision and concentration difficulties the nearer they lived to the mast.
- The performed studies showed the relationship between the incidence of individual symptoms, the level of exposure, and the distance between a residential area and a base station.

Wolf et al, 2004 (Israel)

- A four-fold increase in the incidence of cancer among residents living within 300m radius of a mobile phone mast for between three and seven years was detected.

Eger et al, 2004 (Germany)

A three-fold increase in the incidence of malignant tumours was found after five years' exposure in people living within 400m radius of a mobile phone mast.

Hutter et al, 2006 (Austria)

- A significant correlation between measured power density and headaches, fatigue, and difficulty in concentration in 365 subjects.

Abdel-Rassoul et al, 2007 (Egypt)

Residents living beneath and opposite a long established mobile phone mast reported significantly higher occurrences of headaches, memory changes, dizziness, tremors, depressive symptoms and sleep disturbance than a control group.

Oberfeld et al, 2008 (Austria)

All subjects reported various symptoms during exposure including buzzing in the head, heart palpitations, unwellness, lightheadedness, anxiety, breathlessness, respiratory problems, nervousness, agitation, headache, tinnitus, heat sensation, and depression.

Some Research on RF Radiation to Read

The Bioinititive 2012 Report;

A Comprehensive Overview of the Science by experts in the field. It is broken down into Chapters on various health effects. Notably, it also has the abstracts of the research (All research since 2007 with a SEARCH feature).

It also has color charts so that you can see the levels of radiation and compare this to the effects shown in research studies.

L. Lloyd Morgan, Santosh Kesari, Devra Lee Davis. **Why children absorb more microwave radiation than adults: The consequences.** Journal of Microscopy and Ultrastructure. DOI: 10.1016/j.jmau.2014.06.005. In press. Published online Jul 15, 2014.

- International Cancer registries are showing a rise in brain cancer. Children absorb more microwave radiation, a Class 2 B possible carcinogen than adults.The fetus is in greater danger than children from exposure to MWR. The legal exposure limits have remained unchanged for decades. Cellphone manuals warnings and the 20 cm rule for tablets/laptops violate the “normal operating position” regulation.

Coureau G, Bouvier G, Lebailly P, Fabbro-Peray P, Gruber A, Leffondre K, Guillamo JS, Loiseau H, Mathoulin-Pélissier S, Salamon R, Baldi I. (2014). **Mobile phone use and brain tumours in the CERENAT case-control study.** Occup Environ Med. 71(7), 514-22.

- "However, the positive association was statistically significant in the heaviest users when considering life-long cumulative duration for meningiomas and number of calls for gliomas Risks were higher for gliomas, temporal tumours, occupational and urban mobile phone use.These additional data support previous findings concerning a possible association between heavy mobile phone use and brain tumours."

Davis DL, Kesari S, Soskolne CL, Miller AB, Stein Y.(2013). **Swedish review strengthens grounds for concluding that radiation from cellular and cordless phones is a probable human carcinogen.** Pathophysiology. 20(2), 123-9.

- "If the increased brain cancer risk found in young users in these recent studies does apply at the global level, the gap between supply and demand for oncology services will continue to widen. Many nations, phone manufacturers, and expert groups, advise prevention in light of these concerns by taking the simple precaution of "distance" to minimize exposures to the brain and body. We note than brain cancer is the proverbial "tip of the iceberg"; the rest of the body is also showing effects other than cancers."

Hardell L, Carlberg M, Söderqvist F, Mild K.(2013). **Case-control study of the association between malignant brain tumours diagnosed between 2007 and 2009 and mobile and cordless phone use.** International Journal of Oncology 43(6), 1833-45.

- "This study confirmed previous results of an association between mobile and cordless phone use and malignant brain tumours. These findings provide support for the hypothesis that RF-EMFs play a role both in the initiation and promotion stages of carcinogenesis".

Hardell L, Carlberg M, Hansson, Mild K. (2006). **Pooled analysis of two case-control studies on the use of cellular and cordless telephones and the risk of benign brain tumours diagnosed during 1997-2003**. International Journal of Oncology. 509-18.

- In the multivariate analysis, a significantly increased risk of acoustic neuroma was found with the use of analogue phones.

Aldad et al., **Fetal Radiofrequency Radiation Exposure From 800-1900 Mhz-Rated Cellular Telephones Affects Neurodevelopment and Behavior in Mice.** Scientific Reports, 2012; 2 DOI:

- Mice that were exposed to radiation tended to be more hyperactive and had reduced memory capacity. Authors attributed the behavioral changes to an effect during pregnancy on the development of neurons in the prefrontal cortex region of the brain.

Martin L. Pall. **Microwave electromagnetic fields act by activating voltage-gated calcium channels: why the current international safety standards do not predict biological hazard.** Recent Res. Devel. Mol. Cell Biol. 7(2014).

- "It can be seen from the above that 10 different well-documented microwave EMF effects can be easily explained as being a consequence of EMF VGCC activation: oxidative stress, elevated single and double strand breaks in DNA, therapeutic responses to such EMFs, breakdown of the blood-brain barrier, cancer, melatonin loss, sleep dysfunction, male infertility and female infertility."

Other Documents of Note

US Department of the Interior

"The electromagnetic radiation standards used by the Federal Communications Commission continue to be based on thermal heating, a criterion now nearly 30 years out of date and inapplicable today… Laboratory studies have raised concerns about impacts of low-level, non-thermal electromagnetic radiation...on domestic chicken embryos- with some lethal results"
- Willie Taylor, Director of the Office of Environmental Policy and Compliance of the US Department of the Interior, **Letter to the Department of Commerce in 2014.**

THE CELL PHONE REPORT: TECHNOLOGY EXPOSURES, HEALTH EFFECTS, ENVIRONMENT & HUMAN HEALTH, INC.

John Wargo, Ph.D., professor of Environmental Risk and Policy at Yale University and lead author of the report, said, “The scientific evidence is sufficiently robust showing that cellular devices pose significant health risks to children and pregnant women. The weight of the evidence supports stronger precautionary regulation by the federal

government. The cellular industry should take immediate steps to reduce emission of electromagnetic radiation (EMR) from phones and avoid marketing their products to children."
Recommendations to the Federal Government: Set exposure standards to protect human health.
Recommendations to Individuals: Reduce your exposure to wireless radiation sources.
Read the Full Report

The Parliamentary Assembly of the Council of Europe
Resolution 1815: In 2011 The Parliamentary Assembly of the Council of Europe issued *The Potential Dangers of Electromagnetic Fields and Their Effect on the Environment.* A call to European governments to

- "take all reasonable measures" to reduce exposure to electromagnetic fields "particularly the exposure to children and young people who seem to be most at risk from head tumours."

- The Resolution calls for member states to:Implement "information campaigns about the risk of biological effects on the environment and human health, especially targeting children and young people of reproductive age."

- "*Reconsider* the scientific basis for the present standards on exposure to electromagnetic fields set by the International Commission on Non-Ionising Radiation Protection, which have serious limitations, and apply ALARA principles, covering both thermal effects and the a thermic or biological effects of electromagnetic emissions or radiation."

Norbert Hankin of the EPA, "The FCC's current exposure guidelines...are thermally based, and do not apply to chronic, non-thermal exposure situations." http://www.emrpolicy.org/litigation/case_law/docs/noi_epa_response.pdf

International Scientific Declaration to Health Canada 2014
http://www.c4st.org/images/documents/hc-resolutions/scientific-declaration-to-health-canada-english.pdf

The Seletun Scientific Statement Lower EMF Standards for World Health are Urgently Needed, International Scientists Say http://www.iemfa.org/seletun-statement/

POTENZA PICENA RESOLUTION
http://www.scribd.com/doc/137733972/Potenza-Picena-Scientific-Resolution-Radar-radiofrequency-and-health-risk

AAP submission to the FCC http://apps.fcc.gov/ecfs/document/view?id=7520941318

Chen C, Exposure to 1800 MHz radiofrequency radiation impairs neurite outgrowth of embryonic neural stem cells.Sci Rep.May 29, 2014 http://www.ncbi.nlm.nih.gov/pubmed/24869783?dopt=Abstract

FCC Submission on RF effects on Developing Brain by Dr. Suleyman Kaplan, Department of Histology and Embryology, http://apps.fcc.gov/ecfs/comment/view?id=6017465635

Kesari et al., Effect of 3G cell phone exposure with computer controlled 2-D stepper motor on non-thermal activation of the hsp27/p38MAPK stress pathway in rat brain. Cell Biochem Biophys. 2014 Mar;68(2):347-58. http://www.ncbi.nlm.nih.gov/pubmed/23949848

Aldad T, Gan G, Gao X, Taylor H.(2012). Fetal Radiofrequency Radiation Exposure From 800-1900 Mhz-Rated Cellular Telephones Affects Neurodevelopment and Behavior in Mice. Scientific Reports. 2, 3-12. http://www.nature.com/srep/2012/120315/srep00312/full/srep00312.html

Razavinasab M1, Moazzami K, Shabani M. Maternal mobile phone exposure alters intrinsic electrophysiological properties of CA1 pyramidal neurons in rat offspring.Toxicol Ind Health. 2014 Mar 6. http://www.ncbi.nlm.nih.gov/pubmed/24604340

Gandhi OP, Morgan LL, De Salles AA, Han YY, Herberman RB, Davis DL. (2012). Exposure limits: the underestimation of absorbed cell phone radiation, especially in children. Electromagn Biol Med. 31(1), 3451. http://www.ncbi.nlm.nih.gov/pubmed/21999884

A Rationale for Biologically-based Public Exposure Standards for Electromagnetic Fields (ELF and RF) http://www.bioinitiative.org/

Dr. Erica Mallery--Blythe Physicians' Health Initiative for Radiation and Environment -UK “Electromagnetic Radiation and Children” November 2014 Lecture https://www.youtube.com/watch?v=sNFdZVeXw7M

Dr. Devra Davis scientific presentation on RF radiation at the National Institute of Environmental Health Sciences (NIEHS) https://www.youtube.com/watch?v=wNNSztN7wJc

Blackman,C.,2009.Cell phone radiation: Evidence from ELF and RF studies supporting more inclusive risk identification and assessment. Pathophysiology 16, 205-216. http://www.pathophysiologyjournal.com/article/S0928-4680%2809%2900004-2/abstract

Levitt & Lai,Biological Effects from Exposure to Electromagnetic Radiation Emitted by Cell Tower Base Stations and Other Antenna Arrays, Environmental Reviews, 2010 http://www.researchgate.net/publication/233593841_

Long-term exposure to microwave radiation provokes cancer growth: evidences from radars and mobile communication systems. Yakymenko , 2011 http://www.ncbi.nlm.nih.gov/pubmed/21716201

Carpenter, D. O. Human disease resulting from exposure to electromagnetic fields, Reviews on Environmental Health, Volume 28, Issue 4, Pages 159172. http://www.ncbi.nlm.nih.gov/pubmed/24280284

Epidemiological Evidence for a Health Risk from Mobile Phone Base Stations Khurana, Hardell et al., Int. J Occup. Envir Health, Vol 16(3):263267, 2010 http://www.researchgate.net/publication/45387389

Mortality by neoplasia and cellular telephone base stations. Dode et al., 2011 (Brazil): http://www.sciencedirect.com/science/article/pii/S0048969711005754

Ronni Wolf and Danny Wolf, INCREASED INCIDENCE OF CANCER NEAR A CELLPHONE TRANSMITTER STATION. International Journal of Cancer Prevention VOLUME 1, NUMBER 2, APRIL 2004 http://www.emf-health.com/PDFreports/Israelstudy_celltower.pdf

Horst Eger, Klaus Uwe Hagen, Birgitt Lucas, Peter Vogel, Helmut Voit,The Influence of Being Physically Near to a Cell Phone Transmission Mast on the Incidence of Cancer,n Umwelt·Medizin·Gesellschaft 17,4 2004, http://www.powerwatch.org.uk/news/20041118_naila.pdf

Mortality by neoplasia and cellular telephone base stations. Dode et al., 2011 (Brazil): http://www.sciencedirect.com/science/article/pii/S0048969711005754

Neurobehavioral effects among inhabitants around mobile phone base stations, Neurotoxicology, G. Abdel-Rassoul, et al., (2007) http://www.ncbi.nlm.nih.gov/pubmed/16962663

A cross-sectional case control study on genetic damage in individuals residing in the vicinity of a mobile phone base station.Ghandi et al, 2014 (India) http://www.ncbi.nlm.nih.gov/pubmed/25006864

SAFETY ZONE DETERMINATION FOR WIRELESS CELLULAR TOWER Nyakyi et al, Tanzania (2013) http://ijret.org/Volumes/V02/I09/IJRET_110209029.pdf

Hutter HP et al, (May 2006) Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations, Occup Environ Med. 2006 May;63(5):307-13 http://www.ncbi.nlm.nih.gov/pubmed/1662185

Eskander EF et al, (November 2011) How does long term exposure to base stations and mobile phones affect human hormone profiles? Clin Biochem. 2011 Nov 27. http://www.ncbi.nlm.nih.gov/pubmed/22138021

Investigation on the health of people living near mobile telephone relay stations: Incidence according to distance and sex Santini et al, 2002 (France) http://www.ncbi.nlm.nih.gov/pubmed/12168254

The Microwave Syndrome: A preliminary Study. Navarro E, 2003 (Spain)Pathol Biol (Paris). 2002 Jul;50(6):369-73. http://www.emf-portal.de/viewer.php?aid=13498&l=e

Bortkiewicz A1, Zmyślony M, Szyjkowska A, Gadzicka E. Subjective symptoms reported by people living in the vicinity of cellular phone base stations: review, Med Pr. 2004;55(4):345-51. http://www.ncbi.nlm.nih.gov/pubmed/15620045

IAFF Position on Cell Towers http://www.iaff.org/hs/Facts/CellTowerFinal.asp
"Erroneous Comments Submitted to the FCC on Proposed Cellphone Radiation Standards and Testing."
http://ehtrust.org/wp-content/uploads/2013/11/FCC.pdf

Cell Towers - Wildlife; Electromagnetic Pollution From Phone Masts. Effects on Wildlife; Pathophysiology. (Dr. Alfonso Balmori); 2009

ELSEVIER

Pathophysiology xxx (2009) xxx–xxx

ISP PATHOPHYSIOLOGY

www.elsevier.com/locate/pathophys

Electromagnetic pollution from phone masts. Effects on wildlife

Alfonso Balmori

Direccion General del Medio Natural, Consejería de Medio Ambiente, Junta de Castilla y Leon, C/Rigoberto Cortejoso, 14, 47014 Valladolid, Spain

Received 10 August 2008; received in revised form 28 August 2008; accepted 30 January 2009

Abstract

A review on the impact of radiofrequency radiation from wireless telecommunications on wildlife is presented. Electromagnetic radiation is a form of environmental pollution which may hurt wildlife. Phone masts located in their living areas are irradiating continuously some species that could suffer long-term effects, like reduction of their natural defenses, deterioration of their health, problems in reproduction and reduction of their useful territory through habitat deterioration. Electromagnetic radiation can exert an aversive behavioral response in rats, bats and birds such as sparrows. Therefore microwave and radiofrequency pollution constitutes a potential cause for the decline of animal populations and deterioration of health of plants living near phone masts. To measure these effects urgent specific studies are necessary.

Keywords: Effects on wildlife; Effects on birds; Electromagnetic radiation; Mammals; Microwaves; Mobile telecommunications; Non-thermal effects; Phone masts; Radiofrequencies

1. Introduction

Life has evolved under the influence of two omnipresent forces: gravity and electromagnetism. It should be expected that both play important roles in the functional activities of organisms [1]. Before the 1990's radiofrequencies were mainly from a few radio and television transmitters, located in remote areas and/or very high places. Since the introduction of wireless telecommunication in the 1990's the rollout of phone networks has caused a massive increase in electromagnetic pollution in cities and the countryside [2,3].

Multiple sources of mobile communication result in chronic exposure of a significant part of the wildlife (and man) to microwaves at non-thermal levels [4]. In recent years, wildlife has been chronically exposed to microwaves and RFR (Radiofrequency radiation) signals from various sources, including GSM and UMTS/3G wireless phones and base stations, WLAN (Wireless Local Area Networks), WPAN (Wireless Personal Area Networks such as Bluetooth), and DECT (Digital Enhanced (former European) Cordless Telecommunications) that are erected indiscriminately without studies of environmental impact measuring long-term effects. These exposures are characterized by low intensities, varieties of signals, and long-term durations. The greater portion of this exposure is from mobile telecommunications (geometric mean in Vienna: 73% [5]). In Germany the GSM cellular phone tower radiation is the dominating high frequency source in residential areas [6]. Also GSM is the dominating high frequency source in the wilderness of Spain (personal observation).

Numerous experimental data have provided strong evidence of athermal microwave effects and have also indicated several regularities in these effects: dependence of frequency within specific frequency windows of "resonance-type"; dependence on modulation and polarization; dependence on intensity within specific intensity windows, including superlow power density comparable with intensities from base stations/masts [4,7–9]. Some studies have demonstrated different microwave effects depending on wavelength in the range of mm, cm or m [10,11]. Duration of exposure may be as important as power density. Biological effects resulting from electromagnetic field radiation might depend on dose, which indicates long-term accumulative effects [3,9,12]. Modulated and pulsed radiofrequencies seem to be more effective in producing effects [4,9]. Pulsed waves (in blasts), as well as certain low frequency modulations exert greater

E-mail addresses: abalmori@ono.com, balmaral@jcyl.es.

0928-4680/$ – see front matter © 2009 Published by Elsevier Ireland Ltd.
doi:10.1016/j.pathophys.2009.01.007

biological activity [11,13–15]. This observation is important because cell phone radiation is pulsed microwave radiation modulated at low frequencies [8,9].

Most of the attention on possible biological effects of electromagnetic radiation from phone masts has been focused on human health [5,16–21]. The effects of electromagnetic pollution on wildlife, have scarcely been studied [22–25].

The objective of this review is to detail advances in knowledge of radiofrequencies and microwave effects on wildlife. Future research may help provide a better understanding of electromagnetic field (EMF) effects on wildlife and plants and their conservation.

2. Effects on exposed wildlife

2.1. Effects on birds

2.1.1. Effects of phone mast microwaves on white stork

In monitoring a white stork (*Ciconia ciconia*) population in Valladolid (Spain) in vicinity of Cellular Phone Base Stations, the total productivity in nests located within 200 m of antennae, was 0.86 ± 0.16. For those located further than 300 m, the result was practically doubled, with an average of 1.6 ± 0.14. Very significant differences among total productivity were found ($U = 240$; $P = 0.001$, Mann–Whitney test). Twelve nests (40%) located within 200 m of antennae never had chicks, while only one (3.3%) located further than 300 m had no chicks. The electric field intensity was higher on nests within 200 m (2.36 ± 0.82 V/m) than nests further than 300 m (0.53 ± 0.82 V/m). In nesting sites located within 100 m of one or several cellsite antennae with the main beam of radiation impacting directly (Electric field intensity >2 V/m) many young died from unknown causes. Couples frequently fought over nest construction sticks and failed to advance the construction of the nests. Some nests were never completed and the storks remained passively in front of cellsite antennae. These results indicate the possibility that microwaves are interfering with the reproduction of white stork [23]. (Fig. 1)

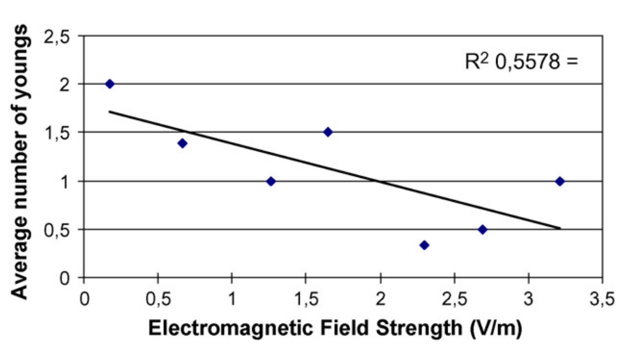


Fig. 1. Average number of youngs and electric field intensity (V/m) in 60 nests of white storks (*Ciconia ciconia*) (Hallberg, Ö with data of Balmori, 2005 [23]).

2.1.2. Effects of phone mast microwaves on house sparrows

A possible effect of long-term exposure to low-intensity electromagnetic radiation from mobile phone (GSM) base stations on the number of house sparrows during the breeding season was studied in Belgium. The study was carried out sampling 150 point locations within six areas to examine small-scale geographic variation in the number of house sparrow males and the strength of electromagnetic radiation from base stations. Spatial variation in the number of house sparrow males was negative and highly significantly related to the strength of electric fields from both the 900 and 1800 MHz downlink frequency bands and from the sum of these bands (Chi-square-tests and AIC-criteria, $P < 0.001$). This negative relationship was highly similar within each of the six study areas, despite differences among areas in both the number of birds and radiation levels. Fewer house sparrow males were seen at locations with relatively high electric field strength values of GSM base stations and therefore support the notion that long-term exposure to higher levels of radiation negatively affects the abundance or behavior of house sparrows in the wild [24].

In another study with point transect sampling performed at 30 points visited 40 times in Valladolid (Spain) between 2002 and 2006, counting the sparrows and measuring the mean electric field strength (radiofrequencies and microwaves: 1 MHz to 3 GHz range). Significant declines ($P = 0.0037$) were observed in mean bird density over time, and significantly low bird density was observed in areas with high electric field strength. The logarithmic regression of the mean bird density vs. field strength groups (considering field strength in 0.1 V/m increments) was $R = -0.87$; $P = 0.0001$ According to this calculation, no sparrows would be expected to be found in an area with field strength >4 V/m [25]. (Fig. 2)

In the United Kingdom a decline of several species of urban birds, especially sparrows, has recently happened [26]. The sparrow population in England has decreased in the last 30 years from 24 million to less than 14. The more abrupt decline, with 75% descent has taken place from 1994 to 2002. In 2002, the house sparrow was added to the Red List of U.K. endangered species [27]. This coincides with the rollout of mobile telephony and the

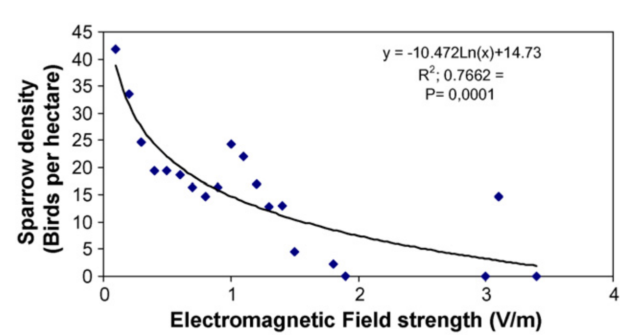


Fig. 2. Mean sparrow density as a function of electric field strength grouped in 0.1 V/m. (Balmori and Hallberg, 2007 [25]).

Please cite this article in press as: A. Balmori, Electromagnetic pollution from phone masts. Effects on wildlife, Pathophysiology (2009), doi:10.1016/j.pathophys.2009.01.007

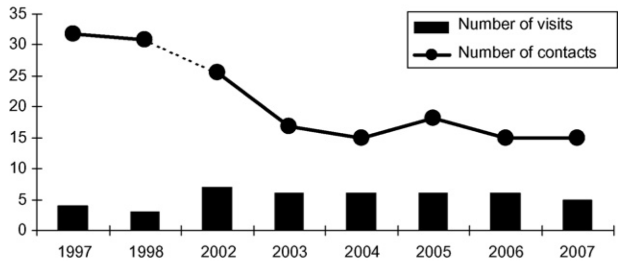


Fig. 3. Annual number of contacts (Mean) for 14 species studied in "Campo Grande" urban park (lack the information of the years 1999–2001).

possible relationship of both circumstances should be investigated.

In Brussels, many sparrows have disappeared recently [28]; similar declines have been reported in Dublin [29]. Van der Poel (cited in Ref. [27]) suggested that sparrows might be declining in Dutch urban centres also.

2.1.3. Effects on the bird community at an urban park

Microwaves may be affecting bird populations in places with high electromagnetic pollution. Since several antennas were installed in proximities of "Campo Grande" urban park (Valladolid, Spain) the bird population has decreased and a reduction of the species and breeding couples has occurred. Between 1997 and 2007, of 14 species, 3 species have disappeared, 4 are in decline and 7 stay stable (Balmori, unpublished data) (Fig. 3). In this time the air pollution (SO_2, NO_2, CO and Benzene) has diminished.

During the research some areas called "silence areas" contaminated with high microwave radiation (>2 V/m), where previously different couples usually bred and later disappeared, have been found. Several anomalies in magpies (*Pica pica*) were detected: plumage deterioration, locomotive problems (limps and deformations in the paws), partial albinism and melanism, especially in flanks [30]. Recently cities have increased cases of partial albinism and melanism in birds (*Passer domesticus*, *Turdus merula* and *P. pica*) (personal observation).

2.1.4. Possible physiological mechanisms of the effects found in birds

Current scientific evidence indicates that prolonged exposure to EMFs, at levels that can be encountered in the environment, may affect immune system function by affecting biological processes [3,31,32]. A stressed immune system may increase the susceptibility of a bird to infectious diseases, bacteria, viruses, and parasites [33].

The plumage of the birds exposed to microwaves looked, in general, discolorated and lack of shine. This not only occurred in ornamental birds; such as peacocks, but also in wild birds; such as, tits, great tits, house sparrows, etc (personal observation). We must mention that plumage deterioration is the first sign of weakening or illnesses in birds since damaged feathers are a sure sign of stress.

Physiological conditions during exposure minimize microwave effects. Radical scavengers/antioxidants might be involved in effects of microwaves [4].

Microwaves used in cellphones produce an athermal response in several types of neurons of the birds nervous system [34]. Several studies addressed behavior and teratology in young birds exposed to electromagnetic fields [23,25,35–37]. Most studies indicate that electromagnetic field exposure of birds generally changes, but not always consistently in effect or in direction, their behavior, reproductive success, growth and development, physiology and endocrinology, and oxidative stress [37]. These results can be explained by electromagnetic fields affecting the birds' response to the photoperiod as indicated by altered melatonin levels [38].

Prolonged mobile phone exposure may have negative effects on sperm motility characteristics and male fertility as has been demonstrated in many studies made in man and rats [39–46]. EMF and microwaves can affect reproductive success in birds [23,25,35,36,47]. EMF exposure affected reproductive success of kestrels (*Falco sparverius*), increasing fertility, egg size, embryonic development and fledging success but reducing hatching success [35,36].

The radiofrequency and microwaves from mobile telephony can cause genotoxic effects [48–55]. Increases in cytological abnormalities imply long-term detrimental effects since chromosomal damage is a mechanism relevant to causation of birth defects and cancer [55].

Long-term continuous, or daily repeated EMF exposure can induce cellular stress responses at non-thermal power levels that lead to an accumulation of DNA errors and to inhibition of cell apoptosis and cause increased permeability of blood–brain barrier due to stabilization of endothelial cell stress fibers. Repeated occurrence of these events over a long period of time (years) could become a health hazard due to a possible accumulation of brain tissue damage. These findings have important implications with regards to potential dangers from prolonged and repeated exposure to non-ionizing radiation [56,57].

Pulsed magnetic fields can have a significant influence on the development and incidence of abnormalities in chicken embryos. In five of six laboratories, exposed embryos exhibited more structural anomalies than controls. If the data from all six laboratories are pooled, the difference for the incidence of abnormalities in exposed embryos and controls is highly significant [58]. Malformations in the nervous system and heart, and delayed embryo growth are observed. The embryo is most sensitive to exposure in the first 24 h of incubation [58]. An increase in the mortality [59] and appearance of morphological abnormalities, especially of the neural tube [13,60,61] has been recorded in chicken embryos exposed to pulsed magnetic fields, with different susceptibility among individuals probably for genetic reasons. A statistically significant high mortality rate of chicken embryos subjected to radiation from a cellphone, compared to the control group exists [62,63]. In another study eggs exposed to a magnetic

field intensity of 0.07 T showed embryonic mortality during their incubation was higher. The negative effect of the magnetic field was manifested also by a lower weight of the hatched chicken [64]. Bioelectric fields have long been suspected to play a causal role in embryonic development. Alteration of the electrical field may disrupt the chemical gradient and signals received by embryo cells. It appears that in some manner, cells sense their position in an electrical field and respond appropriately. The disruption of this field alters their response. Endogenous current patterns are often correlated with specific morphogenetic events [65].

Available data suggests dependencies of genotype, gender, physiological and individual factors on athermal microwave effects [4,9]. Genomic differences can influence cellular responses to GSM Microwaves. Data analysis has highlighted a wide inter-individual variability in response, which was replicated in further experiments [4]. It is possible that each species and each individual, show different susceptibility to radiation, since vulnerability depends on genetic tendency, and physiologic and neurological state of the irradiated organism [15,35–37,61,66–68]. Different susceptibility of each species has also been proven in wild birds exposed to electromagnetic fields from high-voltage power lines [47].

2.2. *Effects on mammals*

2.2.1. *Alarm and aversion behavior*

Rats spent more time in the halves of shuttle boxes that were shielded from 1.2 GHz. Microwaves irradiation. The average power density was about 0.6 mW/cm^2. Data revealed that rats avoided the pulsed energy, but not the continuous energy, and less than 0.4 mW/cm^2 average power density was needed to produce aversion [69]. Navakatikian & Tomashevskaya [70] described a complex series of experiments in which they observed disruption of rat behavior (active avoidance) from radiofrequency radiation. Behavioral disruption was observed at a power density as low as 0.1 mW/cm^2 (0.027 W/kg). Mice in an experimental group exposed to microwave radiation expressed visible individual panic reaction, disorientation and a greater degree of anxiety. In the sham exposed group these deviations of behavior were not seen and all animals show collective defense reaction [71]. Microwave radiation at 1.5 GHz pulsing 16 ms. At 0.3 mW/cm^2 power density, in sessions of 30 min/day over one month produced anxiety and alarm in rabbits [72].

Electromagnetic radiation can exert an aversive behavioral response in bats. Bat activity is significantly reduced in habitats exposed to an electromagnetic field strength greater than 2 V/m [73]. During a study in a free-tailed bat colony (*Tadarida teniotis*) the number of bats decreased when several phone masts were placed 80 m from the colony [74].

2.2.2. *Deterioration of health*

Animals exposed to electromagnetic fields can suffer a deterioration of health and changes in behavior [75,76].

There was proof of frequent death in domestic animals; such as, hamsters and guinea pigs, living near mobile telecommunication base stations (personal observation).

The mice in an experimental group exposed to microwave radiation showed less weight gain compared to control, after two months. The amount of food used was similar in both groups [71]. A link between electromagnetic field exposure and higher levels of oxidative stress appears to be a major contributor to aging, neurodegenerative diseases, immune system disorders, and cancer in mammals [33].

The effects from GSM base transceiver station (BTS) frequency of 945 MHz on oxidative stress in rats were investigated. When EMF at a power density of 3.67 W/m^2, below current exposure limits, were applied, MDA (malondialdehyde) level was found to increase and GSH (reduced glutathione) concentration was found to decrease significantly ($P < 0.0001$). Additionally, there was a less significant ($P = 0.0190$) increase in SOD (superoxide dismutase) activity under EM exposure [77].

2.2.3. *Problems in reproduction*

In the town of Casavieja (Ávila, Spain) a telephony antenna was installed that had been in operation for about 5 years. Then some farmers began blaming the antenna for miscarriages in many pigs, 50–100 m from the antenna (on the outskirts of the town). Finally the topic became so bad that the town council decided to disassemble the antenna. It was removed in the spring 2005. From this moment onwards the problems stopped (C. Lumbreras personal communication).

A Greek study reports a progressive drop in the number of rodent births exposed to radiofrequencies. The mice exposed to 0.168 μW/cm^2 become sterile after five generations, while those exposed to 1.053 μW/cm^2 became sterile after only three generations [22].

In pregnant rats exposed to 27.12 MHz continuous waves at 100 μW/cm^2 during different periods of pregnancy, half the pregnancies miscarried before the twentieth day of gestation, compared to only a 6% miscarriage rate in unexposed controls, and 38% of the viable foetuses had incomplete cranial ossification, compared to less than 6% of the controls. Findings included a considerable increase in the percentage of total reabsorptions (post-implantation losses consequent to RF radiation exposure in the first post-implantation stage). Reduced body weight in the exposed dams reflected a negative influence on their health. It seems that the irradiation time plays an important role in inducing specific effects consequent to radiofrequency radiation exposure [78]. There was also a change in the sex ratio, with more males born to rats that had been irradiated from the time of conception [2]. Moorhouse and Macdonald [79] find a substantial decline in female Water Vole numbers in the radio-collared population, apparently resulting from a male skew in the sex ratios of offspring born to this population. Recruits to the *radio-tracked* population were skewed heavily in favour of males (43:13). This suggests that radio-collaring of females caused male-skewed sex ratios.

Please cite this article in press as: A. Balmori, Electromagnetic pollution from phone masts. Effects on wildlife, Pathophysiology (2009), doi:10.1016/j.pathophys.2009.01.007

Mobile phone exposure may have negative effects on sperm motility characteristics and male fertility in rats [46]. Other studies find a decrease of fertility, increase of deaths after birth and dystrophic changes in their reproductive organs [11]. Intermittent exposure showed a stronger effect than continuous exposure [4]. Brief, intermittent exposure to low-frequency EM fields during the critical prenatal period for neurobehavioral sex differentiation can demasculinize male scent marking behavior and increase accessory sex organ weights in adulthood [80].

In humans, magnetic field exposures above 2.0 mG were positively associated with miscarriage risk [81]. Exposure of pregnant women to mobile phone significantly increased foetal and neonatal heart rate, and significantly decreased the cardiac output [82].

2.2.4. Nervous system

Microwaves may affect the blood brain barrier which lets toxic substances pass through from the blood to the brain [83]. Adang et al. [84] examined the effect of microwave exposure to a GSM-like frequency of 970 MHz pulsed waves on the memory in rats by means of an object recognition task. The rats that have been exposed for 2 months show normal exploratory behavior. The animals that have been exposed for 15 months show derogatory behavior. They do not make the distinction between a familiar and an unfamiliar object. In the area that received radiation directly from "Location Skrunda Radio Station" (Latvia), exposed children had less developed memory and attention, their reaction time was slower and neuromuscular apparatus endurance was decreased [85]. Exposure to cell phones prenatally and, to a lesser degree, postnatally was associated with behavioral difficulties such as emotional and hyperactivity problems around 7 years of age [86]. Electromagnetic radiation caused modification of sleep and alteration of cerebral electric response (EEG) [87–89]. Microwave radiation from phone masts may cause aggressiveness in people and animals (personal observation).

2.3. Effects on amphibians

Disappearance of amphibians and other organisms is part of the global biodiversity crisis. An associated phenomenon is the appearance of large numbers of deformed amphibians. The problem has become more prevalent, with deformity rates up to 25% in some populations, which is significantly higher than previous decades [90]. Balmori [91] proposed that electromagnetic pollution (in the microwave and radiofrequency range) is a possible cause for deformations and decline of some wild amphibian populations.

Two species of amphibians were exposed to magnetic fields at various stages of development. A brief treatment of early amphibian embryos produced several types of abnormalities [92]. Exposure to a pulsed electromagnetic field produced abnormal limb regeneration in adult Newts [93]. Frog tadpoles (*Rana temporaria*) developed under electromagnetic field (50 Hz, 260 A/m) have increased mortality. Exposed tadpoles developed more slowly and less synchronously than control tadpoles and remain at the early stages for longer. Tadpoles developed allergies and EMF caused changes in blood counts [94].

In a current study exposing eggs and tadpoles ($n = 70$) of common frog (*R. temporaria*) for two months, from the phase of eggs until an advanced phase of tadpole, to four telephone base stations located 140 m away: with GSM system 948.0–959.8 MHz; DCS system: 1830.2–1854.8; 1855.2–1879.8 MHz. and UMTS system: 1905–1910; 1950–1965; 2140–2155 MHz. (electric field intensity: 1.847–2.254 V/m). A low coordination of movements, an asynchronous growth, with big and small tadpoles, and a high mortality (90%) was observed. The control group ($n = 70$), under the same conditions but inside a Faraday cage (metallic shielding component: EMC-reinforcement fabrics 97442 Marburg Technic), the coordination of movements was normal, the development was synchronously and the mortality rate was only 4.2% [95].

2.4. Effects on insects

The microwaves may affect the insects. Insects are the basis and key species of ecosystems and they are especially sensitive to electromagnetic radiation that poses a threat to nature [96].

Carpenter and Livstone [97] irradiated pupae of Tenebrio molitor with 10 GHz microwaves at 80 mW for 20–30 min and 20 mW for 120 min obtained a rise in the proportion of insects with abnormalities or dead. In another study exposing fruit flies (*Drosophila melanogaster*) to mobile phone radiation, elevated stress protein levels (Hsp70) was obtained, which usually means that cells are exposed to adverse environmental conditions ('non-thermal shock') [98]. Panagopoulos et al. [99] exposed fruit flies (*D. melanogaster*) to radiation from a mobile phone (900 MHz) during the 2–5 first days of adulthood. The reproductive capacity of the species reduced by 50–60% in modulated radiation conditions (emission while talking on the phone) and 15–20% with radiation nomodulated (with the phone silent). The results of this study indicate that this radiation affects the gonadal development of insects in an athermal way. The authors concluded that radio frequencies, specifically GSM, are highly bioactive and provoke significant changes in physiological functions of living organisms. Panagopoulos et al. [100] compare the biological activity between the two systems GSM 900 MHz and DCS 1800 MHz in the reproductive capacity of fruit flies. Both types of radiation were found to decrease significantly and non-thermally the insect's reproductive capacity, but GSM 900 MHz seems to be even more bioactive than DCS 1800 MHz. The difference seems to be dependent mostly on field intensity and less on carrier frequency.

A study in South Africa finds a strong correlation between decrease in ant and beetle diversity with the

Please cite this article in press as: A. Balmori, Electromagnetic pollution from phone masts. Effects on wildlife, Pathophysiology (2009), doi:10.1016/j.pathophys.2009.01.007

electromagnetic radiation exposure (D. MacFadyen, personal communication.). A decrease of insects and arachnids near base stations was detected and corroborated by engineers and antenna's maintenance staff [101]. In houses near antennas an absence of flies, even in summer, was found.

In a recent study carried out with bees in Germany, only a few bees irradiated with DECT radiation returned to the beehive and they needed more time. The honeycomb weight was lower in irradiated bees [102]. In recent years a "colony collapse disorder" is occurring that some authors relate with pesticides and with increasing electromagnetic pollution [96].

The disappearance of insects could have an influence on bird's weakening caused by a lack of food, especially at the first stages in a young bird's life.

2.5. *Effects on trees and plants*

The microwaves may affect vegetables. In the area that received radiation directly from "Location Skrunda Radio Station" (Latvia), pines (*Pinus sylvestris*) experienced a lower growth radio. This did not occur beyond the area of impact of electromagnetic waves. A statistically significant negative correlation between increase tree growth and intensity of electromagnetic field was found, and was confirmed that the beginning of this growth decline coincided in time with the start of radar emissions. Authors evaluated other possible environmental factors which might have intervened, but none had noticeable effects [103]. In another study investigating cell ultrastructure of pine needles irradiated by the same radar, there was an increase of resin production, and was interpreted as an effect of stress caused by radiation, which would explain the aging and declining growth and viability of trees subjected to pulsed microwaves. They also found a low germination of seeds of pine trees more exposed [104]. The effects of Latvian radar was also felt by aquatic plants. *Spirodela polyrrhiza* exposed to a power density between 0.1 and 1.8 $\mu W/cm^2$ had lower longevity, problems in reproduction and morphological and developmental abnormalities compared with a control group who grew up far from the radar [105].

Chlorophylls were quantitatively studied in leaves of black locust (*Robinia pseudoacacia* L.) seedlings exposed to high frequency electromagnetic fields of 400 MHz. It was revealed that the ratio of the two main types of chlorophyll was decreasing logarithmically to the increase of daily exposure time [106].

Exposed tomato plants (*Lycopersicon esculentum*) to low level (900 MHz, 5 V/m) electromagnetic fields for a short period (10 min) measured changes in abundance of three specific mRNA after exposure, strongly suggesting that they are the direct consequence of application of radio-frequency fields and their similarities to wound responses suggests that this radiation is perceived by plants as an injurious stimulus [107]. Non-thermal exposure to radiofrequency fields induced oxidative stress in duckweed (*Lemna minor*) as well as unespecific stress responses, especially of antioxidative enzymes [108].

For some years progressive deterioration of trees near phone masts have been observed in Valladolid (Spain). Trees located inside the main lobe (beam), look sad and feeble, possibly slow growth and a high susceptibility to illnesses and plagues. In places we have measured higher electric field intensity levels of radiation (>2 V/m) the trees show a more notable deterioration [109]. The tops of trees are dried up where the main beams are directed to, and they seem to be most vulnerable if they have their roots close to water. The trees don't grow above the height of the other ones and, those that stand out far above, have dried tops (Hargreaves, personal communication and personal observation). White and black poplars (*Populus sp*.) and willows (*Salix sp*.) are more sensitive. There may be a special sensitivity of this family exists or it could be due to their ecological characteristics forcing them to live near water, and thus electric conductivity. Other species as *Platanus sp*. and *Lygustrum japonicum*, are more resistant (personal observation). Schorpp [110] presents abundant pictures and explanations of what happens to irradiated trees.

3. Conclusions

This literature review shows that pulsed telephony microwave radiation can produce effects especially on nervous, cardiovascular, immune and reproductive systems [111]:

- Damage to the nervous system by altering electroencephalogram, changes in neural response or changes of the blood–brain barrier.
- Disruption of circadian rhythms (sleep–wake) by interfering with the pineal gland and hormonal imbalances.
- Changes in heart rate and blood pressure.
- Impairment of health and immunity towards pathogens, weakness, exhaustion, deterioration of plumage and growth problems.
- Problems in building the nest or impaired fertility, number of eggs, embryonic development, hatching percentage and survival of chickens.
- Genetic and developmental problems: problems of locomotion, partial albinism and melanism or promotion of tumors.

In the light of current knowledge there is enough evidence of serious effects from this technology to wildlife. For this reason precautionary measures should be developed, alongside environmental impact assessments prior to installation, and a ban on installation of phone masts in protected natural areas and in places where endangered species are present. Surveys should take place to objectively assess the severity of effects.

Acknowledgment

The author is grateful to Denise Ward and Örjan Hallberg.

References

[1] J.M.R. Delgado, Biological effects of extremely low frequency electromagnetic fields, J. Bioelectr. 4 (1985) 75–91.
[2] A. Firstenberg, Microwaving Our Planet: The Environmental Impact of the Wireless Revolution, 11210, Cellular Phone Taskforce, Brooklyn, NY, 1997.
[3] A.L. Galeev, The effects of microwave radiation from mobile telephones on humans and animals, Neurosci. Behav. Physiol. 30 (2000) 187–194.
[4] I. Belyaev, Non-thermal biological effects of microwaves, Microw. Rev. 11 (2005) 13–29, http://www.mwr.medianis.net/pdf/Vol11No2-03-IBelyaev.pdf.
[5] H.P. Hutter, H. Moshammer, P. Wallner, M. Kundi, Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations, Occup. Environ. Med. 63 (2006) 307–313.
[6] T. Haumann, U. Munzenberg, W. Maes, P. Sierck, HF-radiation levels of GSM cellular phone towers in residential areas, in: 2nd International Workshop on Biological effects of EMFS, Rhodes, Greece, 2002.
[7] W.R. Adey, Tissue interactions with non-ionizing electromagnetic fields, Physiol. Rev. 61 (1981) 435–514.
[8] G.J. Hyland, Physics and biology of mobile telephony, Lancet 356 (2000) 1–8.
[9] H. Lai, Biological effects of radiofrequency electromagnetic field, in: Encyclopaedia of Biomaterials and Biomedical Engineering, 2005, doi:10.1081/E-EBBE-120041846, pp. 1–8.
[10] S. Kemerov, M. Marinkev, D. Getova, Effects of low-intensity electromagnetic fields on behavioral activity of rats, Folia Med. 41 (1999) 75–80.
[11] N. Nikolaevich, A. Igorevna, and G. Vasil, Influence of high-frequency electromagnetic radiation at non-thermal intensities on the human body (A review of work by Russian and Ukrainian researchers), No place to hide, 3 (Supplement), 2001.
[12] W.R. Adey, Bioeffects of mobile communications fields: possible mechanisms for cumulative dose. in: N. Kuster, Q. Balzano, J.C. Lin, (Eds.), Mobile communications safety, New York: Chapman & Hall, 1997, pp. 95–131.
[13] A. Úbeda, M.A. Trillo, L. Chacón, M.J. Blanco, J. Leal, Chick embryo development can be irreversibly altered by early exposure to weak extremely-low-frequency magnetic fields, Bioelectromagnetics 15 (1994) 385–398.
[14] I.U.G. Grigoriev, Role of modulation in biological effects of electromagnetic radiation, Radiats. Biol. Radioecol. 36 (1996) 659–670.
[15] G.J. Hyland, The physiological and environmental effects of non-ionising electromagnetic radiation, Working document for the STOA Panel, European Parliament, Directorate General for Research, 2001.
[16] R. Santini, J.M. Santini, P. danze, M. Leruz, M. Seigne, Enquête sur la santé de riverains de stations relais: I. Incidences de la distance et du sexe, Pathol. Biol. 50 (2002) 369–373.
[17] R. Santini, P. Santini, J.M. Le Ruz, M. Danze, M. Seigne, Survey study of people living in the vicinity of cellular phone base stations, Electromagn. Biol. Med. 22 (2003) 41–49.
[18] R. Santini, P. Santini, J.M. Danze, P. Le Ruz, M. Seigne, Symptoms experienced by people in vicinity of base stations: II/Incidences of age, duration of exposure, location of subjects in relation to the antennas and other electromagnetic factors, Pathol. Biol. 51 (2003) 412–415.
[19] E.A. Navarro, J. Segura, M. Portolés, C. Gómez Perretta, The microwave syndrome: a preliminary study in Spain, Electromagn. Biol. Med. 22 (2003) 161–169.
[20] G. Oberfeld, E. Navarro, M. Portoles, C. Maestu, C. Gomez-Perretta, The microwave syndrome—further aspects of a Spanish study, in: EBEA Congres Kos, Greece, 2004.
[21] G. Abdel-Rassoul, M.A. Salem, A. Michael, F. Farahat, M. El-Batanouny, E. Salem, Neurobehavioral effects among inhabitants around mobile phone base stations, Neurotoxicology 28 (2007) 434–440.
[22] I.N. Magras, T.D. Xenos, Radiation-induced changes in the prenatal development of mice, Bioelectromagnetics 18 (1997) 455–461.
[23] A. Balmori, Possible effects of electromagnetic fields from phone masts on a population of white stork (*Ciconia ciconia*), Electromagn. Biol. Med. 24 (2005) 109–119.
[24] J. Everaert, D. Bauwens, A possible effect of electromagnetic radiation from mobile phone base stations on the number of breeding House Sparrows (*Passer domesticus*), Electromagn. Biol. Med. 26 (2007) 63–72.
[25] A. Balmori, Ö. Hallberg, The urban decline of the house sparrow (*Passer domesticus*): a possible link with electromagnetic radiation, Electromagn. Biol. Med. 26 (2007) 141–151.
[26] M.J. Raven, D.G. Noble, S.R. Baillie, The breeding bird survey (2002), BTO Research Report 334, British Trust for Ornithology, Thetford, 2003.
[27] J.D. Summers-Smith, The decline of the house sparrow: a review, Brit. Birds 96 (2003) 439–446.
[28] J. De Laet, Ligue Royale Belgue pour la Protection des Oiseaux avec l'Université de Gand, 2004, <http://www.protectiondesoiseaux.be/content/view/801/74/> (Accessed on May 20, 2008).
[29] A. Prowse, The urban decline of the house sparrow, Brit. Birds 95 (2002) 143–146.
[30] A. Balmori, Aves y telefonía móvil. Resultados preliminares de los efectos de las ondas electromagnéticas sobre la fauna urbana, El ecologista 36 (2003) 40–42.
[31] C.K. Chou, A.W. Guy, L.L. Kunz, R.B. Johnson, J.J. Crowley, J.H. Krupp, Long-term, low-level microwave irradiation of rats, Bioelectromagnetics 13 (1992) 469–496.
[32] E.T. Novoselova, E.E. Fesenko, Stimulation of production of tumour necrosis factor by murine macrophages when exposed in vivo and in vitro to weak electromagnetic waves in the centimeter range, Biofizika 43 (1998) 1132–1133.
[33] K.J. Fernie, D.M. Bird, Evidence of oxidative stress in American kestrels exposed to electromagnetic fields, Environ. Res. A 86 (2001) 198–207.
[34] R.C. Beasond, P. Semm, Responses of neurons to an amplitude modulated microwave stimulus, Neurosci. Lett. 33 (2002) 175–178.
[35] K.J. Fernie, D.M. Bird, R.D. Dawson, P.C. Lague, Effects of electromagnetic fields on the reproductive success of American kestrels, Physiol. Biochem. Zool. 73 (2000) 60–65.
[36] K.J. Fernie, N.J. Leonard, D.M. Bird, Behavior of free-ranging and captive American kestrels under electromagnetic fields, J. Toxicol. Environ. Health, Part A 59 (2000) 597–603.
[37] K.J. Fernie, S.J. Reynolds, The effects of electromagnetic fields from power lines on avian reproductive biology and physiology: a review., J. Toxicol. Environ. Health, Part B 8 (2005) 127–140.
[38] K.J. Fernie, D.M. Bird, Effects of electromagnetic fields on body mass and food-intake of American kestrels, Condor 101 (1999) 616–621.
[39] S. Dasdag, M.A. Ketani, Z. Akdag, A.R. Ersay, I. Sar, Ö.C. Demirtas, M.S. Celik, Whole body microwave exposure emitted by cellular phones and testicular function of rats, Urol. Res. 27 (1999) 219–223.
[40] M. Davoudi, C. Brössner, W. Kuber, Der Einfluss elektromagnetischer wellen auf die Spermienmotilität, J. für Urol. Urogynäkol. 9 (2002) 18–22.
[41] I. Fejes, Z. Za Vaczki, J. Szollosi, R.S. Kolosza, J. Daru, L. Kova Cs, L.A. Pa, Is there a relationship between cell phone use and semen quality? Arch. Androl. 51 (2005) 385–393.
[42] P. Stefanis, A. Drakeley, R. Gazvani, D.I. Lewis-Jones, Growing concern over the safety of using mobile phones and male fertility, Arch. Androl. 52 (2006) 9–14.

[43] O. Erogul, E. Oztas, I. Yildirim, T. Kir, E. Aydur, G. Komesli, H.C. Irkilata, M.K. Irmak, A.F. Peker, Effects of electromagnetic radiation from a cellular phone on human sperm motility: an in vitro study, Arch. Med. Res. 37 (2006) 840–843.
[44] A. Agarwal, F. Deepinder, R.K. Sharma, G. Ranga, J. Li, Effect of cell phone usage on semen analysis in men attending infertility clinic: an observational study, Fertil. Steril. 89 (2008) 124–128.
[45] A. Wdowiak, L. Wdowiak, H. Wiktor, Evaluation of the effect of using mobile phones on male fertility, Ann. Agric. Environ. Med. 14 (1) (2007) 169–172.
[46] J.G. Yan, A.M. Gresti, T. Bruce, Y.H. Yan, A. Granlund, H.S. Matloub, Effects of cellular phone emissions on sperm motility in rats, Fertil. Steril. 88 (4) (2007) 957–964.
[47] P.F. Doherty, T.C. Grubb, Effects of high-voltage power lines on birds breeding within the powerlines' electromagnetic fields, Sialia 18 (1996) 129–134.
[48] V. Garaj-Vrhovac, D. Horvat, Z. Koren, The relationship between colony-forming ability, chromosome aberrations and incidence of micronuclei in V79 Chinese hamster cells exposed to microwave radiation, Mutat. Res. 263 (1991) 143–149.
[49] H. Lai, N.P. Singh, Acute low-intensity microwave exposure increases DNA single-strand breaks in rat brain cells, Bioelectromagnetics 16 (1995) 207–210.
[50] S. Balode, Assessment of radio-frequency electromagnetic radiation by the micronucleus test in bovine peripheral erythrocytes, Sci. Total Environ. 180 (1996) 81–85.
[51] I. Belyaev, L. Hillert, E. Markova, R. Sarimov, L. Malmgren, B. Persson, M. Harms-Ringdahl, Microwaves of mobile phones affect human lymphocytes from normal and hypersensitive subjects dependent on frequency, in: 26th Annual Meeting of the Bioelectromagnetics (BEMS), Washington, USA, 2004.
[52] G. Demsia, D. Vlastos, D.P. Matthopoulos, Effect of 910-MHz electromagnetic field on rat bone marrow, Sci. World J. 4 (2004) 48–54.
[53] Reflex, 2004, <http://www.verum-foundation.de/cgi-bin/content.cgi?id=euprojekte01>.
[54] E. Diem, C. Schwarz, F. Adlkofer, O. Jahn, H. Rudiger, Non-thermal DNA breakage by mobile-phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro, Mut. Res. 583 (2005) 178–183.
[55] A.G. Gandhi, P. Singh, Cytogenetic damage in mobile phone users: preliminary data, Int. J. Hum. Genet. 5 (2005) 259–265.
[56] A. Di Carlo, N. Wite, F. Guo, P. Garrett, T. Litovitz, Chronic electromagnetic field exposure decreases HSP70 levels and lowers cytoprotection, J. Cell. Biochem. 84 (2002) 447–454.
[57] D. Leszczynski, S. Joenväärä, J. Reivinen, R. Kuokka, Non-thermal activation of the hsp27/p38MAPK stress pathway by mobile phone radiation in human endothelial cells: molecular mechanism for cancer- and blood-brain barrier-related effects, Differentiation 70 (2002) 120–129.
[58] E. Berman, L. Chacon, D. House, B.A. Koch, W.E. Koch, J. Leal, S. Lovtrup, E. Mantiply, A.H. Martin, G.I. Martucci, K.H. Mild, J.C. Monahan, M. Sandstrom, K. Shamsaifar, R. Tell, M.A. Trillo, A. Ubeda, P. Wagner, Development of chicken embryos in a pulsed magnetic field, Bioelectromagnetics 11 (1990) 169–187.
[59] B.J. Youbicier-Simo, M. Bastide, Pathological effects induced by embryonic and postnatal exposure to EMFs radiation by cellular mobile phones, Radiat. Protect. 1 (1999) 218–223.
[60] A. Úbeda, J. Leal, M.A. Trillo, M.A. Jimenez, J.M.R. Delgado, Pulse shape of magnetic fields influences chick embryogenesis, J. Anat. 137 (1983) 513–536.
[61] J.M. Farrel, T.L. Litovitz, M. Penafiel, The effect of pulsed and sinusoidal magnetic fields on the morphology of developing chick embryos, Bioelectromagnetics 18 (1997) 431–438.
[62] Ju.G. Grigoriew, Influence of the electromagnetic field of the mobile phones on chickens embryo, to the evaluation of the dangerousness after the criterion of this mortality, J. Radiat. Biol. 5 (2003) 541–544.
[63] F. Batellier, I. Couty, D. Picard, J.P. Brillard, Effects of exposing chicken eggs to a cell phone in "call" position over the entire incubation period, Theriogenology 69 (2008) 737–745.
[64] L. Veterány, A. Veterányová, J. Jedlicka, Effect of magnetic field on embryonic mortality, Cesk. Fysiol. 50 (2001) 141–143.
[65] K.B. Hotary, K.R. Robinson, Evidence of a role for endogenous electrical fields in chick embryo development, Development 114 (1992) 985–996.
[66] M. Mevissen, M. Haübler, Acceleration of mammary tumorigenesis by exposure of 7,12-dimethylbenz(a)anthracene-treated female rats in a 50-Hz, 100-μT magnetic field: replication study, J. Toxicol. Environ. Health, Part A 53 (1998) 401–418.
[67] D. Flipo, M. Fournier, C. Benquet, P. Roux, C. Le Boulaire, Increased apoptosis, changes in intracellular Ca^{2+}, and functional alterations in lymphocytes and macrophages after in vitro exposure to static magnetic field, J. Toxicol. Environ. Health, Part A 54 (1998) 63–76.
[68] M. Fedrowitz, K. Kamino, W. Löscher, Significant differences in the effects of magnetic field exposure on 7,12 dimethylbenz (a)anthracene-induced mammary carcinogenesis in two sub-strains of Sprague-Dawley rats, Cancer Res. 64 (2004) 243–251.
[69] A.H. Frey, S.R. Feld, Avoidance by rats of illumination with low power nonionizing electromagnetic energy, J. Comp. Physiol. Psychol. 89 (1975) 183–188.
[70] M.A. Navakatikian, L.A. Tomashevskaya, Phasic behavioral and endocrine effects of microwaves of nonthermal intensity, in: D.O. Carpenter (Ed.), Biological Effects of Electric and Magnetic Fields, 1, Academic Press, San Diego, CA, 1994.
[71] D.D. Krstić, B.J. Đinđić, D.T. Sokolović, V.V. Marković, D.M. Petković, S.B. Radić, The results of experimental exposition of mice by mobile telephones, in: TELSIKS Conference, Serbia and Montenegro, Microw. Rev. (2005) 34–37.
[72] I.U.G. Grigoriev, S.N. Luk'ianova, V.P. Makarov, V.V. Rynskov, N.V. Moiseeva, Motor activity off rabbits in conditions of chronic low-intensity pulse microwave irradiation, Radiat. Biol. Radioecol. 35 (1995) 29–35.
[73] B. Nicholls, P.A. Racey, Bats avoid radar installations: Could electromagnetic fields deter bats from colliding with wind turbines? PLOS One 3 (2007) e297.
[74] A. Balmori Murciélago rabudo–*Tadarida teniotis*, En: Enciclopedia Virtual de los Vertebrados Españoles, Carrascal, L.M., Salvador, A. (Eds.), Museo Nacional de Ciencias Naturales, Madrid, 2004c, <http://www.vertebradosibericos.org/>.
[75] T.A. Marks, C.C. Ratke, W.O. English, Strain voltage and developmental, reproductive and other toxicology problems in dogs, cats and cows: a discussion, Vet. Human Toxicol. 37 (1995) 163–172.
[76] W. Löscher, G. Käs, Conspicuous behavioural abnormalities in a dairy cow herd near a TV and radio transmitting antenna, Pract. Vet. Surg. 29 (1998) 437–444.
[77] A. Yurekli, M. Ozkan, T. Kalkan, H. Saybasili, H. Tuncel, P. Atukeren, K. Gumustas, S. Seker, GSM Base Station Electromagnetic Radiation and Oxidative Stress in Rats, Electromagn. Biol. Med. 25 (2006) 177–188.
[78] S. Tofani, G. Agnesod, P. Ossola, S. Ferrini, R. Bussi, Effects of continuous low-level exposure to radio-frequency radiation on intrauterine development in rats, Health Phys. 51 (1986) 489–499.
[79] T.P. Moorhouse, D.W. Macdonald, Indirect negative impacts of radio-collaring: sex ratio variation in water voles, J. Appl. Ecol. 42 (2005) 91.
[80] R.F. McGivern, R.Z. Sokol, W.R. Adey, Prenatal exposure to a low-frequency electromagnetic field demasculinizes adult scent marking behavior and increases accessory sex organ weights in rats, Teratology 41 (1990) 1–8.
[81] G.M. Lee, R.R. Neutra, L. Hristova, M. Yost, R.A. Hiatt, A Nested Case-Control Study of Residential and Personal Magnetic Field Measures and Miscarriages, Epidemiology 13 (2002) 21–31.

[82] A.Y. Rezk, K. Abdulqawi, R.M. Mustafa, T.M. Abo El-Azm, H. Al-Inany, Fetal and neonatal responses following maternal exposure to mobile phones, Saudi Med. J. 29 (2008) 218–223.
[83] L.G. Salford, A.E. Brun, J.L. Eberhardt, L. Malmgren, B.R. Persson, Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones, Environ. Health Perspect. 111 (2003) 881–893.
[84] D. Adang, B. Campo, A.V. Vorst, Has a 970 MHz Pulsed exposure an effect on the memory related behaviour of rats? in: The 9th European Conference onWireless Technology, September 2006, 2006, pp.
[85] A.A. Kolodynski, V.V. Kolodynska, Motor and psychological functions of school children living in the area of the Skrunda Radio Location Station in Latvia, Sci. Total Environ. 180 (1996) 87–93.
[86] H.A. Divan, L. Kheifets, C. Obel, J. Olsen, Prenatal and postnatal exposure to cell phone use and behavioral problems in children, Epidemiology 19 (2008) 523–529.
[87] K. Mann, J. Roschkle, Effects of pulsed high-frequency electromagnetic fields on human sleep, Neuropsychobiology 33 (1996) 41–47.
[88] A.V. Kramarenko, U. Tan, Effects of high-frequency electromagnetic fields on human EEG: a brain mapping study, Int. J. Neurosci. 113 (2003) 1007–1019.
[89] A.A. Marino, E. Nilsen, C. Frilot, Nonlinear changes in brain electrical activity due to cell phone radiation, Bioelectromagnetics 24 (2003) 339–346.
[90] A.R. Blaustein, P.T.J. Johnson, Explaining frog deformities, Sci. Am. 288 (2003) 60–65.
[91] A. Balmori, The incidence of electromagnetic pollution on the amphibian decline: is this an important piece of the puzzle? Toxicol. Environ. Chem. 88 (2006) 287–299.
[92] W.C. Levengood, A new teratogenic agent applied to amphibian embryos, J. Embryol. Exp. Morphol. 21 (1969) 23–31.
[93] R.H. Landesman, W. Scott Douglas, Abnormal limb regeneration in adult newts exposed to a pulsed electromagnetic field, Teratology 42 (1990) 137–145.
[94] N.M. Grefner, T.L. Yakovleva, I.K. Boreysha, Effects of electromagnetic radiation on tadpole development in the common frog (*Rana temporaria* L.), Russ. J. Ecol. 29 (1998) 133–134.
[95] A. Balmori, in preparation: Phone masts effects on common frog (*Rana temporaria*) tadpoles: An experiment in the city. See the video clips in: http://www.hese-project.org/hese-uk/en/issues/nature.php?id=frogs.
[96] U. Warnke, Bienen, vögel und menschen, Die Zerstörung der Natur durch "Elektrosmog". Kompetenzinitiative, 2007 46 pp.
[97] R.L. Carpenter, E.M. Livstone, Evidence for nonthermal effects of microwave radiation: Abnormal development of irradiated insect pupae, IEEE Trans. Microw. Theor. Tech. 19 (1971) 173–178.
[98] D. Weisbrot, H. Lin, L. Ye, M. Blank, R. Goodman, Effects of mobile phone radiation on reproduction and development in *Drosophila melanogaster*, J. Cell. Biochem. 89 (2003) 48–55.
[99] D.J. Panagopoulos, A. Karabarbounis, L.H. Margaritis, Effect of GSM 900 MHz Mobile Phone Radiation on the Reproductive Capacity of *Drosophila melanogaster*, Electromagn. Biol. Med. 23 (2004) 29–43.
[100] D.J. Panagopoulos, E.D. Chavdoula, A. Karabarbournis, L.H. Margaritis, Comparison of bioactivity between GSM 900 MHz and DCS 1800 MHz mobile telephony radiation, Electromagn. Biol. Med. 26 (2007) 33–44.
[101] A. Balmori, Efectos de las radiaciones electromagnéticas de la telefonía móvil sobre los insectos, Ecosistemas (2006).
[102] H. Stever, J. Kuhn, C.Otten, B.Wunder, W. Harst, Verhaltensanderung unter elektromagnetischer Exposition. Pilotstudie, Institut für mathematik. Arbeitsgruppe, Bildungsinformatik. Universität Koblenz-Landau, 2005.
[103] V.G. Balodis, K. Brumelis, O. Kalviskis, D. Nikodemus, V.Z. y Tjarve, Does the Skrunda radio location station diminish the radial growth of pine trees? Sci. Total Environ. 180 (1996) 57–64.
[104] T. Selga, M. Selga, Response of *Pinus Sylvestris* L. needles to electromagnetic fields. Cytological and ultraestructural aspects, Sci. Total Environ. 180 (1996) 65–73.
[105] I. Magone, The effect of electromagnetic radiation from the Skrunda Radio Location Station on Spirodela polyrhiza (L.) Schleiden cultures, Sci. Total Environ. 180 (1996) 75–80.
[106] D.D. Sandu, C. Goiceanu, A. Ispas, I. Creanga, S. Miclaus, D.E. Creanga, A preliminary study on ultra high frequency electromagnetic fields effect on black locust chlorophylls, Acta Biol. Hung. 56 (2005) 109–117.
[107] D. Roux, Al. Vian, S. Girard, P. Bonnet, F. Paladian, E. Davies, G. Ledoigt, High frequency (900 MHz) low amplitude ($5\,V\,m^{-1}$) electromagnetic field: a genuine environmental stimulus that affects transcription, translation, calcium and energy charge in tomato, Planta 227 (2007) 883–891.
[108] M. Tkalec, K. Malarik, B. Pevalek-Kozlina, Exposure to radiofrequency radiation induces oxidative stress in duckweed *Lemna minor* L., Sci. Total Environ. 388 (2007) 78–89.
[109] A. Balmori, ¿Pueden afectar las microondas pulsadas emitidas por las antenas de telefonía a los árboles y otros vegetales? Ecosistemas (2004), http://www.revistaecosistemas.net/articulo.asp?Id=29&Id_Categoria=1&tipo=otros_contenidos.
[110] V. Schorpp, 2007, <http://www.puls-schlag.org/baumschaeden.htm#linden>.
[111] A. Balmori, Posibles efectos de las ondas electromagnéticas utilizadas en la telefonía inalámbrica sobre los seres vivos, Ardeola 51 (2004) 477–490.

Cell Towers - Wildlife; Testimony of Dr. Albert M. Manville, II, PhD., C.W.B, Before the City of Eugene City Planning Department in Opposition to AT&T/Crossfire's Application for a "Stealth" Communications Tower; May 6, 2015

Testimony of Albert M. Manville, II, Ph.D., C.W. B., and Principal, Wildlife and Habitat Conservation Solutions, LLC, on Behalf of Friends of Amazon Creek, Before the City of Eugene City Planning Department in Opposition to AT&T/Crossfire's Application for a "Stealth" Cellular Communications Tower in the Upper Amazon Creek Corridor

Re: CUP 14-003, please enter into the record.

Date: May 6, 2015

Introduction

I will make a strong case that the approval, placement and operation of a 75-ft "stealth" artificial evergreen tree, cellular (cell) communication tower in the center of the upper Amazon Creek corridor, Eugene, Oregon is inappropriate and incompatible with the City of Eugene's designation of the area as a protected nature area. The specific proposed tower location is at 4060 West Amazon Drive, situated on residentially zoned property owned by Crossfire Ministries. Approving this tower is not in the public and taxpayers' best interest, and will likely harm wildlife and wildlife habitat. In particular, of the more than 300 bird species observed in the Eugene area, potential harm to 7 already designated Birds of Conservation Concern (BCC; USFWS 2008) has troubling implications. The Federal Communications Commission (FCC) does not mandate 100% cell phone coverage and there is no provision under the 1996 Telecommunications Act (TCA) for such a requirement (Manville 2001, as discussed at the conference in the Levitt 2001 Proceedings). There are alternatives to building this structure, including in more developed areas that contain degraded habitats, collocated on another existing antenna structure, and away from habitat critically important to birds and other wildlife. All are preferable alternatives — discussed beyond.

I will assert that the City Ordinance No. 9.5750, "Telecommunication Devices — Siting Requirements and Procedures," is an inadequate document to be solely used by the City of Eugene's Planning Department to assess, approve or deny this AT&T/Crossfire cell tower permit application. While there is a growing database on effects of cell tower radiation to human health and safety which are prevented from introduction into testimony by Section 704 of the TCA, my focus in this testimony is on impacts from collisions and radiation to wildlife, specifically migratory birds — which represent environmental damage not addressed by Section 704.

Regarding impacts to wildlife, not only must the City of Eugene consider current FCC rules and regulations for licensing this cell tower, they must also consider the court ordered findings from the 2008 American Bird Conservancy et al. *v.* FCC lawsuit, which FCC lost on appeal in the Federal Court of Appeals for the District of Columbia Circuit. These include considerations under the Migratory Bird Treaty Act (MBTA) for impacts to protected migratory birds (above and beyond issues pertaining to the Endangered Species Act [ESA]), as well as compliance under the National Environmental Policy Act (NEPA) and its regulations. NEPA review includes opportunities for public review, comment, request for preparation of an Environmental Assessment (EA), and even litigation.

Additionally, and the focus of this testimony, are the rules and regulations implemented by the U.S. Fish and Wildlife Service (herein USFWS or Service) under the MBTA, and the Bald and Golden Eagle Protection Act (BGEPA), both which are strict liability, criminal statutes.

Lastly, the growing documented effects of low level, non-ionizing electromagnetic radiation which will be transmitted from and received by this tower are of growing concern to wildlife, including "take." FCC's current radiation standards are based solely on thermal heating, a standard 30 years out of date and inapplicable based on laboratory and field research on birds (and other animals) published in refereed scientific journals (summarized below), not to mention numerous other credible scientific findings (e.g., Panagopoulos and Margaritis 2008).

While FCC continues to fail to address low level impacts from non-ionizing radiation, the U.S. Department of Commerce's National Telecommunications and Information Administration (NTIA) and its First Responder Network Authority (FirstNet) reacted positively to a letter sent from the Department of Interior to NTIA on February 7, 2014 (USDOI 2014) — Enclosure A in that letter which I authored. FirstNet is building, operating and maintaining the first high-speed, nationwide wireless broadband network dedicated to public safety. FirstNet plans to systematically review the impacts of their nationwide broadcast network from injury, crippling loss and death to migratory birds from collisions with communication towers, and will begin addressing impacts from non-ionizing electromagnetic radiation emitted from them. Unlike the FCC which continues to deny effects from non-ionizing radiation, NTIA is acknowledging and addressing them through a systematic NEPA review process.

This complex situation and conflicting rules and regulations clearly suggest that members of the City Planning Department review each issue individually, but overall assess them collectively.

Summary of My Training and Experience

I worked as a federal wildlife biologist for 17 years, retiring in June 2014 from my position as a Senior Wildlife Biologist with the Division of Migratory Bird Management, USFWS, Headquarters Office, Arlington, VA. I was the Service's national lead on issues related to anthropogenic causes of bird mortality, including from communication towers. In that capacity, I chaired the Communication Tower Working Group (looking at both avian-tower collisions and avian-radiation impacts), working closely with the FCC, Federal Aviation Administration, other federal agencies, all the large tower and cell phone trade associations, several cell phone companies, scientists, academicians, and consultants. I was the USFWS project officer for the cutting edge tower lighting study at Michigan State Police communication towers (Gehring et al. 2009, Gehring et al. 2011), served as the project officer for a U.S. Coast Guard tall communication tower study, developed a cell tower research monitoring protocol for the U.S. Forest Service (Manville 2002), developed a peer-reviewed cell tower radiation monitoring protocol, and represented USFWS as lead reviewer on many communication tower projects from cell towers to tall, digital television towers.

I earned a B.S. in zoology from Allegheny College, Meadville, PA. Following a 4-year stint in the U.S. Navy where I was trained by the Department of State as a Mandarin Chinese linguist and interpreter working at the National Security Agency (including training on the use of

communication devices and equipment), I completed an M.S. in natural resources and wildlife management from the University of Wisconsin, Stevens Point, and earned a Ph.D. at Michigan State University in wildlife ecology and management. More recently, I was designated as a "Certified Wildlife Biologist" (C.W.B.) by The Wildlife Society.

I have served on the Board of Managers of the Washington Biologists' Field Club, and was nominated for membership in the Cosmos Club. I also am a member of numerous professional societies. Additionally, I served on the Steering Committee of the Endangered Species Coalition before being offered a branch chief's position in 1997 with the Division of Migratory Bird Management. In 1999, I received the Conservation Service Award from the Secretary of Interior for bird conservation efforts with the electric utility industry.

I have testified over 40 times before Congress and other governmental bodies in regard to environmental issues and conducted numerous research efforts globally. I have published more than 175 professional and popular papers, chapters, and book reviews, and given more than 160 invited public presentations. I served on the Editorial Advisory Board of the *Nature Conservancy* Magazine, was the wildlife consultant for the Walt Disney/Touchstone Pictures production of the movie *White Fang* (based on Jack London's book), and I have conducted hundreds of radio and television interviews, and been extensively quoted in the print media. I have held teaching positions at Michigan State University, George Mason University, and the USDA Graduate School Evening Programs, and I currently (since 2000) am an Adjunct Professor for Johns Hopkins University's Krieger School of Arts and Sciences, DC campus, teaching graduate classes in wildlife ecology, and conservation biology and wildlife management. In October 2014, I created a limited liability company certified by the Commonwealth of Virginia State Corporation Commission. The LLC is named, *Wildlife and Habitat Conservation Solutions LLC.*

<u>Why Are Migratory Birds Important?</u>

<u>Migratory Birds</u>:

Migratory birds — i.e., those that migrate across U.S., Canadian and/or Mexican borders, of which 1,027 species are currently protected in the United States (50 C.F.R. 10.13 list), are a public trust resource, meaning they belong to everyone. Almost all North American continental birds are protected by the MBTA. The Act implements and regulates bilateral protocols with Canada, Mexico, Japan and Russia. It is a strict liability statute; proof of criminal intent in the injury or killing of birds is not required by authorities for cases to be made.

The statute and its regulations protect migratory birds, their parts, eggs, feathers and nests from un-permitted possession and "take" (i.e., un-permitted injury, crippling loss, or killing). Migratory bird nests are protected during the breeding season while eagle nests are protected year-round. Efforts are currently underway by USFWS to develop a permit where un-permitted "take" could be allowed under MBTA; that process began in 2001. A Federal permit is required to possess a migratory bird and its parts, but the MBTA currently provides *no* provision for the accidental or incidental "take" (causing injury, crippling loss, or death) of a protected migratory bird, even when otherwise normal, legal business practices or personal activities are involved, <u>such as the operation of an AT&T/Crossfire cell tower that results in bird injuries and/or deaths</u>.

The U.S. Congress noted the "take" of even one protected migratory bird to be a violation of the Statute, with fines and criminal penalties that can be extensive.

Eagles:

Bald and Golden Eagles are also protected by the BGEPA, another strict liability statute. "Take" under BGEPA is more expansive than under MBTA, and includes pursuit, shooting, poisoning, capturing, killing, trapping, collecting, molesting and disturbing both species (50 C.F.R. 22.3). It is important to note that eagles do not simply need to be killed or injured to be in violation of the Eagle Act. Un-permitted disturbance such as noise from AT&T's tower construction or tower maintenance could disturb Bald Eagles. Example: An adult breeding pair of Bald Eagles is documented as nesting at Skinner Butte (*Eugene Register Guard*, 4/22/15) and may forage in the upper Amazon Creek corridor. "Disturbance take" could result in reduced survivorship of adults, juveniles and chicks, affecting their population viability. These are potential criminal offenses. While USFWS does not generally require that companies such as AT&T possess eagle "take" permits, without them, "disturbance take" and "take resulting in mortality" (50 C.F.R. 22.26), and for "take of nests" (50 C.F.R. 22.27) are potential criminal offenses.

Status of Migratory Birds:

Migratory birds are in trouble, including impacts from individual structures such as ATT's proposed cell tower which cumulatively can have huge impacts to bird populations. There are growing numbers of Birds of Conservation Concern (BCCs; USFWS 2008) — species in decline but not yet ready for federal listing as threatened or endangered under ESA. Currently there are 273 species (out of 1,027 protected birds) and subspecies on the national BCC, Service Regional BCC and Bird Conservation Region BCC lists, providing an early warning of likely peril unless the population trends are reversed. At least 7 BCCs may be present in the Amazon Creek corridor (discussed below).

Additionally, there are 92 endangered and threatened bird species on the ESA List of Threatened and Endangered Species. Collectively, BCC and ESA-listed birds represent at least 366 bird species (36%) in decline — some seriously — with numbers of both listed and BCC species growing (Manville 2013a). Additionally, the USFWS is also tasked to maintain stable or increasing breeding populations of Bald and Golden Eagles under implementing regulations of BGEPA and compliance with NEPA — including for cell towers. As noted above, at least 1 breeding pair of Bald Eagles is nesting at nearby Skinner Butte, and could be impacted by the proposed tower either through collision with its metal branches while foraging in the upper Amazon Creek area, or by its radiation should they establish a nest in the tower itself or nest nearby.

Birds are critically important to us all, providing key ecosystem services that fuel a multi-billion dollar industry through pollination, insect and weed-seed control efforts in the agribusiness and forest products industries. Without migratory birds, there would be untold additional problems requiring more pesticide, herbicide, and other chemical use. Feeding, photographing, and watching migratory birds — popular activities that draw residents from all around Eugene to the Amazon Creek nature area — also fuels a $32 billion/yr recreation industry in the U.S., representing an estimated 20% of the U.S. adult population involved in these endeavors. It is asserted that more adults in the U.S. feed, photograph and watch birds than play golf (Carter

2013, MountainNature.com 2015). Bird watching in the Amazon Creek corridor represents one of many opportunities for the public to become involved with nature (FriendsofAmazonCreek.org). For example, the Edison Elementary School's River Spies Program (riverspies.blogspot.com) recently had young children directly engaged in a bird survey in the corridor. This proposed cell tower is out of character with the public's interest and these recreational endeavors.

Impacts of Collisions and Radiation to Migratory Birds from Communication Towers

Collisions:

Migratory birds have been documented killed in single night, mass mortality collision events with communication towers, guy-support wires, and tower lights in the U. S. since 1948 — (Aronoff 1949, summarized in Manville 2007) — including at unguyed, unlit, < 200-ft above-ground-level (AGL) cell towers like AT&T's proposed tower. For example, in October 2005, W. Evans reported hundreds of migratory birds documented killed by collisions with short, unguyed and unlit cell towers in the Northeast, sometimes in significant numbers of hundreds of birds/cell tower/night (e.g., W. Evans cited in Manville 2007). While the probability of high levels of collisions with AT&T's proposed tower is small given its valley location and modest height, collision mortality or injury — especially with the rigid metal branches of the stealth tower while navigating through the neighborhood in inclement weather — is certainly likely.

During nighttime navigation, birds can be overwhelmed by inclement weather events, forcing bird fall-out, significant reductions in flight heights, and resultant confusion in identifying safe structures (Manville 2014a). Currently an estimated 6.8 million birds/yr are killed in the U.S. and Canada (Longcore et al. 2012). The vast majority of these bird deaths are in the U.S. In another review, at least 13 species of BCCs were estimated to suffer annual mortality of 1-9% of their estimated total population based solely on tower and tower structure collisions in the U.S. or Canada (Longcore et al. 2013). These include estimated annual mortality of > 2% for the Yellow Rail (a BCC species possibly present but scarce in Eugene in the summer and on the National BCC list), Swainson's Warbler, Pied-bill Grebe (a BCC possibly present in Eugene but scarce and on the BCC Regional list), Bay-breasted Warbler, Golden-winged Warbler, Worm-eating Warbler, Prairie Warbler, and Ovenbird. Up to 350 species of birds have been documented killed at communication towers (Manville 2014a). Each time more birds are injured or killed at individual communication towers such as that proposed by AT&T, these "takings" add to the overall impacts to bird populations not unlike the phenomenon of the "death by a thousand cuts."

More than 300 species of migratory birds have been recorded in the Eugene area (Welcome to Birding Eugene 2015). Of these — in addition to the Yellow Rail and Pied-billed Grebe mentioned above — at least 5 additional BCC species are designated on the USFWS's (2008:23) Bird Conservation Region (BCR) 4, Northwestern Interior Forest U.S. BCC list. These include the Horned Grebe, Peregrine Falcon (previously ESA delisted), Lesser Yellowlegs, Short-billed Dowitcher, and Olive-sided Flycatcher. Since these species are already in decline and in trouble, potential impacts from AT&T's proposed tower *could* further negatively affect them. By not building that tower in a sensitive natural area that attracts such birds, potential risk is reduced.

Radiation:

Not until recently have the effects of low-level, non-thermal electromagnetic radiation on domestic and wild birds been made public. For example, laboratory studies by T. Litovitz (2000 pers. comm.) and DiCarlo et al. (2002) from the standard 915 MHz cell phone frequency on domestic chicken embryos showed that radiation from extremely low levels (0.0001 the level emitted by the average digital cell phone) caused heart attacks and deaths in some embryos; controls were unaffected (DiCarlo et al. 2002). However, the effects of microwave (and other) radiation from communication towers on nesting and roosting wild birds are yet unstudied in the U.S. In Europe, impacts have been well documented. Balmori (2005) found strong negative correlations between levels of tower-emitted microwave radiation and bird breeding, nesting, and roosting in the vicinity of electromagnetic fields in Spain. He documented nest and site abandonment, plumage deterioration, locomotion problems, and death in House Sparrows, White Storks, Rock Doves, Magpies, Collared Doves, and other species. While these species had historically been documented to roost and nest in these areas, Balmori (2005) did not observe these symptoms prior to construction of the cellular phone towers. Balmori and Hallberg (2007) and Everaert and Bauwens (2007) found similar strong negative correlations among male House Sparrows.

The electromagnetic radiation standards used by the FCC continue to be based on thermal heating, a criterion now 30 years out of date and inapplicable today. This is primarily due to the lower levels of radiation output from microwave-powered communication devices such as cellular telephones and their cell towers, Wi-Fi, so called “smart meters,” and other sources of point-to-point communications; levels typically lower than from microwave ovens. FCC, to date, has been unwilling to update their regulatory standards.

In February 2014, the Director of the Department of Interior’s Office of Environmental Policy and Compliance sent a letter to the U.S. Commerce Department’s NTIA suggesting regulatory compliance by its FirstNet, a newly created entity, implementing development of emergency broadcast systems nationwide (USDOI 2014). Included in those recommendations are inadequacies which NTIA has acknowledged and is now proceeding to address. These included inadequacies for conserving migratory birds in Enclosure A which I authored while working for the Division of Migratory Bird Management, USFWS. In it, I provided recommendations for addressing bird injury, crippling loss, and death from communication tower and metal branch collisions; and research needs for beginning to address impacts from non-ionizing electromagnetic radiation emitted from such towers.

Given the findings of the studies mentioned above, and an extensive meta-review of the published studies by Panagopoulos and Margaritis (2008), field studies should be conducted in the U.S. by third-party, independent research entities with no vested interest in the outcomes to validate potential impacts of communication tower radiation — both direct and indirect — to birds and other animals. However, to date, these have yet to be performed. Rather than building the Crossfire tower, AT&T should fund an independent radiation study in the U.S. I have already developed a preliminary study protocol.

Amazon Creek Corridor and AT&T/Crossfire’s Proposed Stealth Cell Tower

Until recently, companies such as AT&T applying for broadcast licenses through the FCC would normally have requested a “categorical exclusion” for review of a license application such as for

this proposed Crossfire tower (i.e., FCC Environmental Compliance regulation, Section 106 National Historic Preservation Act process). Only where a federally-listed migratory bird (Section 4, ESA) and/or its "critical habitat" (Section 3, ESA) were present at or near the tower site would environmental review have been required under FCC regulations. Otherwise, environmental review and public input would likely have been excluded. That situation is now changing.

It is true that City and state governments have been constrained in some ways by Section 704 of the Telecommunications Act of 1996. Although Section 704 states that new tower construction requires approval of the state or local governing authority (e.g., City of Eugene), it clarifies that local zoning authority may be preempted by FCC. <u>However, new develops may arguably have changed this situation</u>. Case law in 2 municipal cases have resulted in towns being able to supersede Section 704 provisions and deny cell tower permit approval. In Sprint Spectrum *v.* Willoth, Docket 98-7442, U.S. Court of Appeals 2nd Circuit, 1999, Sprint challenged the Planning Board of the Town of Ontario, New York, over their rejection of permits for several cell towers. Ontario, NY, prevailed. In Verizon Wireless *v.* Clarkstown, NY, Southern District of New York, 00 Cir. 3029 (CM), 2000, the court denied plaintiff's claim that the town of Clarkstown had violated TCA by denying cell tower permit approval, and dismissed all claims against Clarkstown.

Due to the lawsuit by The American Bird Conservancy et al. *v.* FCC which the Commission lost on appeal (516 F.3d; D.C. Cir. 2008; *American Bird Conservancy*), effects of communication towers to migratory birds must now be included as part of the court ordered review process, and the public must be provided a meaningful opportunity to request an EA under NEPA for proposed towers that FCC considers "categorically excluded." While the FCC's interim rulemaking focused initially on tall (i.e., those ≥ 450 ft AGL) towers, that height limit has been discarded and the December 2011 statement by FCC Commissioner Michael J. Copps in regard to the order of remand (FCC 11-181) is telling. In the Matter of Effects of Communication Towers on Migratory Birds, WT Docket No. 03-187, Order of Remand, Commissioner Copps stated, *"Today, at long last, the Commission has responded to the DC Circuit's rebuke to our previous rules that fell short of meeting our responsibilities under the National Environmental Policy Act, the Endangered Species Act, and the Migratory Bird Treaty Act. While I am disappointed it has taken nearly four years to respond to the court, I am encouraged these interim rules will give more parties greater opportunity to register their concerns about migratory birds when a tower goes up…"*

Summarizing FCC's current position, the Commission must now address impacts to migratory birds in addition to any avian-ESA issues. As such, AT&T — whose frequencies are licensed by FCC — cannot ignore migratory bird issues including adjacent bird concentrations in the Amazon Creek area and adjacent Park areas; possible "take" from collisions with the metal, stealth tower arms; impacts of non-ionizing tower radiation on breeding, roosting, and feeding birds; Bald Eagles which could be disturbed or otherwise impacted by tower construction; and USFWS updated 2013 voluntary communication tower siting, placement, operation and decommissioning guidance (Manville 2013b). Before I retired from USFWS, I updated the Service's voluntary 2000 communication tower guidance which I had previously co-authored, sharing the updates with the FCC (Manville 2013b).

It is also important to note that if the City of Eugene's Planning Department were to approve the AT&T/Crossfire permit application, and "take" from this tower were to occur, there could be potential culpability for both the City and AT&T. First, the "take" would be un-permitted. USFWS does not currently issue incidental take permits for accidental/incidental injuries or deaths. Instead, the agency recommends that towers be collocated on other existing structures; be built in already heavily developed areas with already degraded wildlife habitats; and that natural habitats important to birds and other wildlife be avoided. Implementing these efforts will minimize potential "take" as a consequence.

To understand how agents with the Service's Office of Law Enforcement and prosecuting environmental attorneys with the Department of Justice make and prosecute cases respectively, I quote from a power line manual (APLIC 2006) an explanation of how prosecution generally works. As the Service has previously stated (e.g., APLIC 2006:21), "*although the MBTA ha[s] no provision for allowing take, the USFWS realizes that some birds will be killed even if all reasonable measures to avoid it are used. The USFWS Office of Law Enforcement [OLE] carries out its mission to protect migratory birds through investigations and enforcement, as well as by fostering relationships with individuals, companies, and industries that have programs to minimize their impacts on migratory birds. Since a take cannot be authorized, it is not possible to absolve individuals, companies, or agencies from liability even if they implement avian mortality avoidance or similar conservation measures. However, the OLE does have enforcement discretion and focuses on those individuals, companies, or agencies that take migratory birds without regard for their actions and the law, especially when conservation measures had been developed but had not been implemented."*

Clearly, the Service's 2000 voluntary communication tower guidance and the same guidance I updated and provided to FCC in 2013 (Manville 2013b) have "conservation measures" which USFWS has recommended be implemented. While I am no longer a federal employee, I do as a private citizen continue to recommend that AT&T and the City of Eugene implement these guidelines. Recapping, these include collocating on another antenna structure, selecting a more environmentally benign site, building in a more degraded habitat, and avoiding wetlands.

Due to the proximity of the proposed tower to the Amazon Creek nature area, killing or injuring migratory birds would be incompatible with the purpose and intent of this City in designating the special status of this area. This is an important migration corridor for many species of songbirds, is likely used by the 2 BCC waterbirds mentioned above, and provides habitat protection and natural resource conservation as important tenets of this part of the Eugene parks system. In addition, millions of taxpayer dollars have been spent to create and maintain this green space and wildlife corridor (T. Taylor, Supervisor, Eugene Parks & Open Space Division public presentation). Construction of the tower is out of character and incompatible with the purpose and intent of this protected nature area. It will almost certainly create environmental damage not addressed through Section 704 of the Telecommunications Act, and because federal funds were in part used to develop and upgrade the Amazon Creek corridor, a federal "nexus" may have resulted. This nexus allows the public through the NEPA process to review, comment, testify, request an EA, and even litigate due to this funding situation since the area would be affected by the tower.

Conclusions and Recommendations

While the proposed AT&T/Crossfire cell tower is of modest height (75 ft AGL) and will be constructed in a cryptic, stealth-like design mimicking a pine tree, ostensibly to draw little human notice and conceal its identity from the public, I am unaware of any evidence to show that such design is any less attractive to migratory birds seeking nesting or roosting structures. Furthermore, although un-guyed and unlit, migratory birds still have been documented killed by collisions with monopole and lattice towers, sometimes in significant numbers of hundreds of birds/cell tower/night (e.g., W. Evans cited in Manville 2007). Adjacent lighting from streetlights could, for example, result in significant bird attraction and collisions with rigid metal branches during inclement weather events.

The effects of low level radiation are also growing concerns. While FCC has yet to recognize them, NTIA has. The effects of radiation from studies conducted in Europe are troubling. The situation provides an opportunity for AT&T to fund an independent, third-party study to better understand the impacts of telecommunication structures on migratory birds and other species.

Summarizing, based on my previous review and analysis, here are the issues I recommend the City of Eugene Planning Department consider in addressing AT&T's Crossfire tower application:

- Is this cell tower necessary?
- The collision and RF safety of this proposed tower to migratory birds must be evaluated. Cell towers, including short stealth designs such as this one, are not benign structures.
- The potential environmental effects of this proposed tower to birds, and impacts on the Amazon Creek habitat area, must be assessed. This review not only includes City Ordinance No. 9.5750, but FCC rules and regulations (Section 106 NHPA), FCC court-ordered determinations and other recent case law, environmental damage that will be created other than what is addressed by Section 704 of the TCA (which deals only with human health, not environmental damage), existing regulations under the MBTA (which contains no incidental "take" provisions), and impacts due to potential violations of regulations under BGEPA, ESA and NEPA review processes.
- Is there potential culpability to the City of Eugene if the tower application is approved and "take" subsequently occurs?
- An assessment should be made of the 7 BCCs including validation that the Yellow Rail, Pied-bill Grebe, Horned Grebe, Peregrine Falcon, Lesser Yellowlegs, Short-billed Dowitcher, and Olive-sided Flycatcher may be present in the corridor and could be negatively affected if they are present.
- A recognition of potential "disturbance take" of Bald Eagles.
- There is a conundrum between FCC's outdated radiation standards based on thermal heating and NTIA's recognition that low level, non-ionizing radiation can affect migratory birds, and is being addressed through NEPA review. However, until independent research can be conducted and results analyzed, no recommendations can yet be provided on this issue — other than to proceed using the precautionary approach and to keep emissions as low as reasonably achievable.

- Use updated, 2013 USFWS voluntary communication tower guidelines, most especially including "conservation measures" which will minimize migratory bird "take" — i.e., collocation, selecting other existing degraded and developed sites, and avoiding designated natural habitat areas.
- Assess the overall compatibility of this proposed tower with the purposes, intents, public concerns and taxpayer-funded efforts involved with maintaining the Amazon Creek corridor natural area.

In conclusion, on behalf of Friends of Amazon Creek, I recommend that the City of Eugene Planning Department reject this particular cell tower application.

Respectfully submitted,

Albert M. Manville, II, Ph.D., C.W.B.
Wildlife and Habitat Conservation Solutions, LLC

<u>Literature Cited</u>

Aronoff, A. 1949. The September migration tragedy. Linnaean News-Letter 3(1):2.

Avian Power Line Interaction Committee. 2006. Suggested practices for avian protection on power lines: the state of the art in 2006. Edison Electric Institute, APLIC, and the California Energy Commission. Washington, DC, and Sacramento, CA. 207 pp.

Avian Power Line Interaction Committee. 2012. Reducing avian collisions with power lines: the state of the art in 2012. Edison Electric Institute and APLIC, Washington, DC. 159 pp.

Balmori, A. 2005. Possible effects of electromagnetic fields from phone masts on a population of White Stork (*Ciconia ciconia*). Electromagnetic Biology and Medicine 24:109-119.

Balmori, A., and O. Hallberg. 2007. The urban decline of the House Sparrow (*Passer domestics*): a possible link with electromagnetic radiation. Electromagnetic Biology and Medicine 26:141-151.

Carter, E. 2013. Birding in the United States: demographic and economic analyses. U.S. Fish and Wildlife Service Report 2011-1, 16 pp. Arlington, VA

DiCarlo, A., N. White, F. Guo, P. Garrett, and T. Litovitz. 2002. Chronic electromagnetic field exposure decreases HSP70 levels and lowers cytoprotection. Journal Cellular Biochemistry 84: 447-454.

Everaert, J., and D. Bauwens. 2007. A possible effect of electromagnetic radiation from mobile phone base stations not he number of breeding House Sparrows (*Passer demesticus*). Electromagnetic Biology and Medicine 26:63-72.

Gehring, J., P. Kerlinger, and A.M. Manville, II. 2009. Communication towers, lights and birds: successful methods of reducing the frequency of avian collisions. Ecological Applications 19(2): 505-514.

Gehring, J., P. Kerlinger, and A.M. Manville, II. 2011. The role of tower height and guy wires on avian collisions with communication towers. Journal of Wildlife Management 75(4): 848-855.

Longcore, T., C. Rich, P. Mineau, B. MacDonald, D.G. Bert, L.M. Sullivan, E. Mutrie, S.A. Gauthreaux, Jr., M.L. Avery, R.C. Crawford, A.M. Manville, II, E.R. Travis, and D. Drake. 2012. An estimate of avian mortality at communication towers in the United States and Canada. PLoSONE 7(4) 17 pp, Open Access.

Longcore, T., C. Rich, P. Mineau, B. MacDonald, D.G. Bert, L.M. Sullivan, E. Mutrie, S.A. Gauthreaux, Jr., M.L. Avery, R.C. Crawford, A.M. Manville, II, E.R. Travis, and D. Drake. 2013. Avian mortality at communication towers in the United States and Canada: which species, how many, and where? Biological Conservation 158: 410-419.

Manville, A.M. II. 2001. Avian mortality at communication towers: steps to alleviate a growing problem. Pp. 75-86, 227-228. *In:* B.B. Levitt (ed.). Proceedings of the "Cell Towers Forum" State of the Science/State of the Law, December 2, 2000, Litchfield, CT. ISBN 1-884820-62-X.

Manville, A.M., II. 2002. Protocol for monitoring the impacts of cellular telecommunication towers on migratory birds within the Coconino, Prescott, and Kaibab National Forests, Arizona. Peer-reviewed research monitoring protocol requested by and prepared for the U.S. Forest Service. Division of Migratory Bird Management, USFWS, 9 pp. March 2002.

Manville, A.M., II. 2007. Comments of the U.S. Fish and Wildlife Service submitted electronically to the FCC on 47 CFR Parts 1 and 17, WT Docket No. 03-187, FCC 06-164, Notice of Proposed Rulemaking, "Effects of Communication Towers on Migratory Birds." February 2, 2007. 32 pp.

Manville, A.M. II. 2009. Towers, turbines, power lines and buildings – steps being taken by the U.S. Fish and Wildlife Service to avoid or minimize take of migratory birds at these structures. Pp 262-272 *In* T.D. Rich, C. Arizmendi, D.W. Demarest, and C. Thompson (eds.). Tundra to Tropics: Connecting Birds, Habitats and People. Proceedings 4th International Partners in Flight Conference, McAllen, Texas.

Manville, A.M., II. 2013a. Anthropogenic-related bird mortality focusing on steps to address human-caused problems. Invited White Paper for the Anthropogenic Panel, 5th International Partners in Flight Conference, August 27, 2013, Snowbird, Utah. Division of Migratory Bird Management, USFWS, peer-reviewed white paper. 16 pp.

Manville, A.M., II. 2013b. U.S. Fish and Wildlife Service (USFWS) revised guidelines for communication tower design, siting, construction, operation, retrofitting, and decommissioning — Suggestions based on previous USFWS recommendations to FCC regarding WT Docket No. 03-187, FCC 06-164, Notice of Proposed Rulemaking, "Effects of Communication Towers on Migratory Birds," Docket No. 08-61, FCC's Antenna Structure Registration Program, and

Service 2012 Wind Energy Guidelines. Division of Migratory Bird Management, Arlington, VA. 5 pp.

Manville, A.M., II. 2014a. Status of U.S. Fish and Wildlife Service developments with communication towers with a focus on migratory birds: updates to Service staff involved with tower issues — a webinar. Talking Points and Literature Citations, Available to the Public. March 7, 13 pp.

Panagopoulos, D.J., and L.H. Margaritis. 2008. Mobile telephony radiation effects on living organisms. Chapter 3, pp. 107-149, *In* A.C. Harper and R.V. Buress (eds.), Mobile Telephones, Nova Science Publishers, Inc. ISBN: 978-1-60456-436-5.

United States Department of Interior. 2014. ER 14/0001-14/0004. Letter to Mr. Eli Veenendaal, Natl. Telecommunications and Information Administration, US Dept. Commerce. Signed by W.R. Taylor, Director Office of Environmental Policy and Compliance, Office of Secretary, DOI. February 7, 8 pp, in the public arena.

U.S. Fish and Wildlife Service. 2008. Birds of Conservation Concern 2008. United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, VA. 85 pp. (http://www.fws.gov/migratorybirds/>).

Welcome to Birding Eugene. 2015. Checklist of Fern Ridge Birds. Lane County Audubon Soc., Eugene Parks Foundation, and City of Eugene. thefarleys.us/BirdingEugene/Welcome.html

Cell Towers-Plants; Radiofrequency Radiation Injures Trees Around Mobile Phone Base Stations. Science of the Total Environment. (Waldmann-Selsam et al); 2016

Science of the Total Environment 572 (2016) 554–569

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Radiofrequency radiation injures trees around mobile phone base stations

Cornelia Waldmann-Selsam [a], Alfonso Balmori-de la Puente [b], Helmut Breunig [c], Alfonso Balmori [d,*]

[a] Karl-May-Str. 48, 96049 Bamberg, Germany
[b] C/Navarra, 1 5°B, 47007 Valladolid, Spain
[c] Baumhofstr. 39, 37520 Osterode, Germany
[d] Consejería de Medio Ambiente, Junta de Castilla y León, C/Rigoberto Cortejoso, 14 47071 Valladolid, Spain

HIGHLIGHTS

- High frequency nonionizing radiation is becoming increasingly common.
- This study found a high level of damage to trees in the vicinity of phone masts.
- Deployment has been continued without consideration of environmental impact.

GRAPHICAL ABSTRACT

Bernartzky (1986), revisited:

ARTICLE INFO

Article history:
Received 6 June 2016
Received in revised form 19 July 2016
Accepted 6 August 2016
Available online xxxx

Editor: D. Barcelo

Keywords:
Electromagnetic radiation
Effects on trees
Phone masts
Radiofrequencies

ABSTRACT

In the last two decades, the deployment of phone masts around the world has taken place and, for many years, there has been a discussion in the scientific community about the possible environmental impact from mobile phone base stations. Trees have several advantages over animals as experimental subjects and the aim of this study was to verify whether there is a connection between unusual (generally unilateral) tree damage and radiofrequency exposure. To achieve this, a detailed long-term (2006–2015) field monitoring study was performed in the cities of Bamberg and Hallstadt (Germany). During monitoring, observations and photographic recordings of unusual or unexplainable tree damage were taken, alongside the measurement of electromagnetic radiation. In 2015 measurements of RF-EMF (Radiofrequency Electromagnetic Fields) were carried out. A polygon spanning both cities was chosen as the study site, where 144 measurements of the radiofrequency of electromagnetic fields were taken at a height of 1.5 m in streets and parks at different locations. By interpolation of the 144 measurement points, we were able to compile an electromagnetic map of the power flux density in Bamberg and Hallstadt. We selected 60 damaged trees, in addition to 30 randomly selected trees and 30 trees in low radiation areas (n = 120) in this polygon. The measurements of all trees revealed significant differences between the damaged side facing a phone mast and the opposite side, as well as differences between the exposed side of damaged trees and all other groups of trees in both sides. Thus, we found that side differences in measured values of power flux density corresponded to side differences in damage. The 30 selected trees in low radiation areas (no visual

* Corresponding author.
E-mail addresses: balmaral@jcyl.es, abalmori@ono.com (A. Balmori).

http://dx.doi.org/10.1016/j.scitotenv.2016.08.045

contact to any phone mast and power flux density under 50 μW/m^2) showed no damage. Statistical analysis demonstrated that electromagnetic radiation from mobile phone masts is harmful for trees. These results are consistent with the fact that damage afflicted on trees by mobile phone towers usually start on one side, extending to the whole tree over time.

1. Introduction

For many years, there has been a discussion in the scientific community about whether artificial radiofrequency radiation has harmful effects on living organisms and, more specifically, on the environmental impact from mobile phone base stations (Panagopoulos et al., 2016). Trees have several advantages over animals as experimental subjects: they are continuously exposed to radiation in a constant orientation in the electromagnetic field due to their inability to move (Vian et al., 2016). Additionally, it is possible to easily document changes over time, such as disturbed growth, dying branches, and premature colour change of leaves. Moreover, the damage to trees is objective and cannot be attributed to psychological or psychosomatic factors.

Plants are specialized in the interception of electromagnetic radiation (light) but radiofrequency radiation impact on plants, which is becoming common in the environment because of the exponential use of mobile phone technology, has received little attention and his physiological effect has long been considered negligible.

Since the mid-twentieth century, several researchers have investigated the effects of electromagnetic radiation on plants, both in the laboratory (Kiepenheuer et al., 1949; Brauer, 1950; Harte, 1950, 1972; Jerman et al., 1998; Lerchl et al., 2000; Sandu et al., 2005; Roux et al., 2006, 2008; Sharma et al., 2009; Tkalec et al., 2005, 2009; Beaubois et al., 2007; Kundu and IEEE, 2013; Pesnya and Romanovsky, 2013; Cammaerts and Johansson, 2015; Grémiaux et al., 2016; Vian et al., 2016), and in nature (field observations) (Bernatzky, 1986; Volkrodt, 1987, 1991; Selga and Selga, 1996; Balodis et al., 1996; Haggerty, 2010). Both kinds of study have frequently found pernicious effects.

Around the world, phone masts have been deployed in the last two decades everywhere. Preliminary published studies have indicated deleterious effects of radiofrequency radiation on trees (Balmori, 2004; Van't Wout, 2006; Schorpp, 2011; Waldmann-Selsam, 2007; Waldmann-Selsam and Eger, 2013), cautioning that research on this topic is extremely urgent (Balmori, 2015). However, these early warnings have had no success and deployment has been continued without consideration of environmental impact.

In a review of the effects of environmental microwaves on plants (Jayasanka and Asaeda, 2013), it was indicated that effects depend on the plant family and the growth stage, as well as the exposure duration, frequency, and power density. This review concluded that most studies that address the effects of microwaves on animals and plants have documented effects and responses at exposures below limits specified in the electromagnetic radiation exposure guidelines and it is therefore necessary to rethink these guidelines (Jayasanka and Asaeda, 2013).

Since 2005, on the occasion of medical examinations of sick residents living near mobile phone base stations, changes in nearby trees (crown, leaves, trunk, branches, growth…) were observed at the same time as clinical symptoms in humans occurred. Since 2006 tree damages in the radiation field of mobile phone base stations were documented (http://kompetenzinitiative.net/KIT/KIT/baeume-in-bamberg/). In the radio shadow of buildings or that one of other trees, the trees stayed healthy.

Additionally, unilateral crown damage, beginning on the side facing an antenna, pointed to a possible link between RF-EMF (Radiofrequency Electromagnetic Fields) and tree damage. We carried out measurements on both sides of unilaterally damaged trees. Most of the trees had been exposed to RF-EMF for at least five years. Each time we found considerable differences between the measured values on the damaged and on the healthy side.

The aim of the present study was to verify whether there is a connection between unusual (generally unilateral) tree damage and radiofrequency exposure.

2. Materials and methods

The official information of 65 mobile phone sites in the neighbouring cities Bamberg and Hallstadt was extracted from the EMF database (EMF-Datenbank) of the German Federal Network Agency (Bundesnetzagentur, in March 2011 and October 2015). Each site certificate ("Standortbescheinigung") provides information on the mounting height of antennas, the number and main beam direction of the sector antennas, the number of omnidirectional antennas (ND), the number of other transmitters, as well as the horizontal and vertical safety distances. The current specifications of the transmission facilities are available at: http://emf3.bundesnetzagentur.de/karte/Default.aspx

On most of the 65 mobile phone sites several sector antennas emitting RF-EMF with differences in frequency, modulation and other physical characteristics are installed (GSM 900, GSM 1800, UMTS, LTE (4th generation), TETRA). In 2011 there was a total of 483 sector antennas, in 2015 a total of 779 sector antennas.

Numerical code, address and UTM 32N coordinates for the 65 Mobile phone (base stations) sites in Bamberg and Hallstadt are shown in Table 1.

Between 2006 and 2015 there was observation and documentation of tree damages. There were some preliminary measurements on both sides of unilaterally damaged trees and approximately 700 trees in Bamberg and Hallstadt were visited. The condition of numerous trees has been documented in photographs. The photographs record the state of trees showing damage patterns not attributable to diseases, pests, drought or other environmental factors in order to monitor damage and growth over several years (in 2006, Olympus FE-100 was used; since 2007, Panasonic DMC-FZ50 was used).

In 2015 we selected a polygonal study site, with an approximate area of 30 km^2, which includes partial municipalities of Bamberg and Hallstadt (70 km^2). The study area with the location of the phone masts in the layer of natural areas and municipalities is shown in Fig. 1. In this area, different measurements (see below) were done both for having a radiation map and for knowing which are the incident power densities beside different trees. In spite of the fact that measurements are changing continuously, they do not show significant differences between times (own data, see below).

In this polygon, we performed 144 measurements of the radiofrequency electromagnetic fields at a height of 1.5 m at different points in the city. These measurements were taken in streets and parks and allowed the preparation of an electromagnetic map of Bamberg and Hallstadt with their interpolation. The measurements were carried out with an EMF-broadband analyzer HF 59B (27–3300 MHz) and the horizontal-isotrope broadband antenna UBB27_G3, (Gigahertz Solutions). Measurements of the sum peak values of power flux density were in μW/m^2, which can be converted in V/m.

In general, a sector antenna covers an angle of 120° and the radiation of the sector antennas is distributed in main and secondary beams, bundled vertically and horizontally. The high-frequency emissions are reflected/diffracted and/or absorbed by buildings and trees. Therefore,

Table 1
Official information of the 65 mobile phone base stations in Bamberg and Hallstadt.

Code number	Adress in Bamberg and Hallstadt	X	Y	Code number	Adress in Bamberg and Hallstadt	X	Y
1	Altenburg	634268	5527019	34	Ludwigstr. 25 (Post)	636318	5529177
2	Am Borstig 2	636070	5531636	35	Luitpoldstr. 51	636241	5529232
3	Am Hirschknock	637511	5532267	36	Mainstraße, Ladekai 2	633924	5530319
4	An der Breitenau 2	637253	5530650	37	Mainstraße, Ladekai 3	633816	5530130
5	(An der Breitenau, P&R) ca.	637259	5526912	38	Margaretendamm 28	635341	5529331
6	(Artur-Landgraf-Straße)	635183	5526912	39	Memmelsdorfer Straße (Post) ca.	637769	5531392
7	Breitäckerstr. 9	632965	5529621	40	Memmelsdorfer Str. 208a	637568	5531191
8	Coburger Str. 6a	635877	5529951	41	Memmelsdorfer Str. 208a	634861	5528541
9	Coburger Str. 35	635252	5530468	42	Mußstr. 1	634949	5528827
10	Erlichstr. 47/51	637291	5527903	43	Pödeldorfer Str. 144	637828	5529305
11	Franz-Ludwig-Str. 7	635843	5528490	44	Rheinstr. 16 ca.	632910	5530367
12	Geisfelder Str. 30	637689	5528020	45	Robert-Bosch-Str. 40	637767	5528292
13	Grüner Markt 1	635624	5528370	46	Schildstr. 81	637049	5529049
14	Grüner Markt 23	635640	5528565	47	Schranne 3	635511	5528166
15	Gutenbergstr. 20	638448	5527180	48	Schützenstr. 23	636197	5527961
16	Hainstr. 4	635945	5528229	49	Schwarzenbergstr. 50	636762	5528732
17	Hainstr. 39	636341	5527550	50	Siemensstr. 37-43	638091	5528505
18	Hauptsmoorstr. 26a	638223	5530558	51	Theresienstr. 32	637487	5527866
19	Hauptsmoorwald, Pödeldorfer Straße	639683	5529635	52	Unterer Kaulberg 4	635350	5528084
20	Hauptsmoorwald, Geisfelder Straße	639890	5528022	53	Von-Ketteler-Str. 2	637905	5527553
21	Heiliggrabstr. 15	636054	5529240	54	Wilhelmsplatz 3	636316	5528259
22	Heinrichsdamm 1	635849	5528723	55	Zollnerstr. 181	637772	5530133
23	Heinrichsdamm 33a, P&R	636748	5527529	56	Heganger 18	634327	5530982
24	Hohenlohestr. 7	634794	5526480	57	Biegenhofstr. 13	633963	5531045
25	Kantstr. 33	637161	5530333	58	Seebachstr. 1	634399	5531764
26	Katzenberg	635374	5528266	59	Landsknechtstr.	634800	5531918
27	Kirschäckerstr. 37	636649	5530756	60	Lichtenfelser Str.	634864	5532621
28	(Kloster-Langheim-Str. 8)	637190	5529182	61	Michelinstr. 130 ca.	635629	5532106
29	Kronacher Str. 50	636722	5531496	62	Margaretendamm	634991	5529497
30	Lagerhausstr. 4-6	634850	5529871	63	Mainstr. 36a/Kiliansplatz	634326	5532386
31	Lagerhausstr. 19	634304	5530136	64	Bamberger Straße	635964	5526050
32	(Laurenziplatz 20)	635207	5527404	65	Würzburger Str. 76	635359	5526709
33	Ludwigstr. 2	635207	5529103				

due to existing obstacles there is an inhomogeneous radiofrequency field distribution. Buildings and vegetation (trees and foliage) can shield and reduce radiation and thus affect the quality of signal propagation (e.g. Meng and Lee, 2010). Living material is not a perfect dielectric object and interferes with high frequency electromagnetic fields in a way that depends upon several parameters, including the general shape, conductivity, and density of the tissue, and the frequency and amplitude of the electromagnetic radiation (Vian et al., 2016).

In the polygon mentioned before we selected 60 trees showing unilateral damage. The selection was limited by the fact that we were able to measure with the telescopic rod only up to a height of 6 m. Many trees (*Tilia, Betula, Quercus, Populus, Picea*) showing damage above the

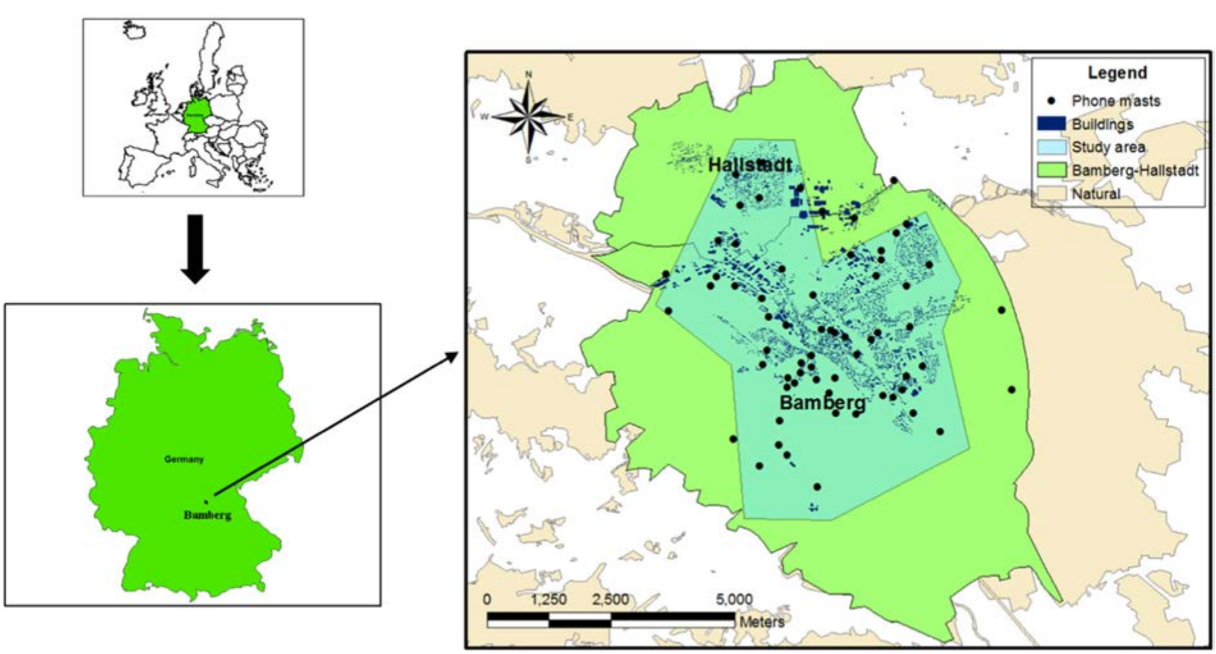


Fig. 1. The study area with the location of the phone masts in the layer of natural areas, buildings, and municipalities.

height of 6 m could not be included. The measurements at the trees were done between April and October 2015. *Acer platanoides*, *Carpinus betulus*, *Tilia* sp., *Taxus baccata* and *Thuja occidentalis* are widely spread in Bamberg and Hallstadt and can be reached for measurements. Therefore they are the most represented species.

The selected 60 trees from the study polygon show damage patterns that are not usually attributable to harmful organisms, such as diseases (fungi, bacteria, viruses) and pests (insects, nematodes) or other environmental factors (water stress, heat, drought, frost, sun, compaction of the soil, air and soil pollutants).

The main features of damage from this source are:

- Trees are mainly affected on one side (showing side differences and unilateral damage) and can appear in any orientation. The damage only originates on one side.
- Damage appears without external indications that the tree is infested with insects, nematodes, fungi, bacteria or viruses.
- Damage appears on trees, which have previously grown well. Damage appears on once healthy trees within one or two years after Antennas were put into operation.
- Damage increases from the outside to the inner part of the crown over time.
- Trees of different species in the same location also show damage.
- Damage appears in favourable (gardens, parks) as well as in unfavourable locations.
- Trees in the same location, but that are shielded by buildings or other trees, are healthy.

For these damaged trees, we used 13 damage codes that may be recognised with the naked eye (for explanations, see Table 2). In order to explain each type of damage visually, a photograph was added for each damage code.

Table 2
Tree damage codes.

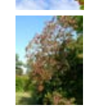
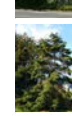
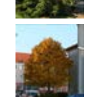
01 Damage only on one side: The tree shows damage only on one side. The damage can be recognized with the naked eye.	
02 Crown transparency (sparse leaves or needles): The number of leaves or needles is reduced. The crown transparency increases from year to year.	
03 Brown leaves (start at leaf margins): The leaves begin to turn brown in june. The browning starts at the leaf margins. It looks similar to effects by salt.	
04 Colour change of leaves prematurely: Leaves become yellow, red or brown (in the whole) early in the year.	
05 Tree leaves fall prematurely: The leaves begin to fall already from june on.	
06 Dead branches: Over a period of some years it can be observed how little and big branches die.	
07 Tip of the main guide dried.	
08 Irregular growth. The growth of deciduous and coniferous trees can be disturbed in different manners. One observation is that trees bend to a side.	
09 Not grow in height: Trees often stop to grow in height. The height was not measured. Only the visual impression was valuated.	
10 Colour change of needles. Needles can change their colour to yellow, red or brown.	
11 Dead parts were trimmed down: When bigger branches die, it becomes necessary to remove these parts for the sake of security of people passing.	
12 Damage on different sides: The trees show damages on different sides.	
13 No damage: The tree shows the typical habitus of its species. With the naked eye no damage can be seen.	

Table 3
144 selected points in Bamberg and Hallstadt with their measurements and UTM coordinates.

Number	Streets and parks in Bamberg and Hallstadt	Measurement μW/m²	X	Y	Number	Streets and parks in Bamberg and Hallstadt	Measurement μW/m²	X	Y
1	Wassermannpark	2300	637395	5530345	73	Ludwigstraße/Zollnerstraße	50	636228	5529444
2	Memmelsdorfer Str. 209	1830	637581	5531113	74	Landratsamt, Ludwigstraße, Einfahrt	670	636422	5529044
3	Holunderweg	10	638125	5530967	75	Wilhelmsplatz, Mitte	460	636250	5528263
4	Hauptsmoorstraße/Seehofstraße	3600	638039	5530857	76	Amalienstr. 16	16570	636303	5528086
5	Greifffenbergstr. 79	4210	638349	5530855	77	Otttostr. 7a	120	636133	5527878
6	Heimfriedweg 16	870	638393	5530621	78	Schönbornstr. 3	3640	636251	5527696
7	AWO, Innenhof, Parkplatz	3920	638223	5530584	79	Hainspielplatz	1530	636229	5527403
8	Ferdinand-Tietz-Str. 40	2600	637883	5530616	80	P&R Heinrichsdamm, Parkplatz bei Kirschen	3400	636706	5527667
9	Ferdinand-Tietz-Str. 38	80	637889	5530601	81	P&R Heinrichsdamm, südöstlich des Senders, Eichen	1690	636755	5527504
10	Petrinistr. 20	1340	637797	5530514	82	Luisenhain, Höhe Wasserwerk	260	636895	5526482
11	Petrinistr. 32	4700	637891	5530449	83	Kapellenstraße	2120	637050	5528148
12	Zollnerstraße 181	9300	637773	5530102	84	Geisfelder Str. 9, Gärtnerei	740	637410	5528164
13	Wassermannstr. 14	540	637424	5530125	85	Gereuthstr. 8	30	637621	5527424
14	Feldkirchenstraße/Kantstraße	2620	636803	5530069	86	Distelweg, Innenhof	15	637881	5527160
15	Breslaustr. 20	3890	637392	5530431	87	Am Sendelbach BSC 1920	30	637331	5526877
16	Berliner Ring	16920	637188	5530786	88	Am Sendelbach, Kleingartenanlage	10	637542	5526222
17	Rodezstr. 3	3780	637044	5530765	89	Robert-Bosch-Straße	2060	637504	5528200
18	Am Spinnseyer 3	880	637545	5530764	90	Ludwigstraße/Memmelsdorfer Straße	1000	635974	5529708
19	Kirschäckerstr. 24	4290	636655	5530857	91	Coburger Straße, Neubau Studentenwohnheim	3460	635867	5529878
20	Kammermeisterweg	810	636283	5530282	92	Coburger Straße, junge Platane	3400	635835	5529941
21	Eichendorff-Gymnasium, Hof	6340	637194	5529084	93	Gundelsheimer Str. 2	9000	635783	5529680
22	Starkenfeldstraße/Pfarrfeldstraße	3660	637092	5529138	94	Hallstadter Straße	12	635232	5530212
23	Parkplatz auf der Westseite der Polizei	9020	636921	5528970	95	Gerberstraße/Benzstraße	1280	635108	5530546
24	Starkenfeldstraße, Höhe Polizei	1120	636975	5529061	96	Coburger Straße, Einfahrt Fitnesszentrum	2000	635326	5530508
25	Starkenfeldstr. 2	860	637527	5529216	97	Kleintierzuchtanlage	890	635380	5530622
26	Pödeldorfer Str., Haltestelle	2180	636965	5529217	98	Margaretendamm, Eingang ehemaliges Hallenbad	1300	635455	5529178
27	Kindergarten St. Heinrich, Eingang	6450	637712	5529364	99	Margaretendamm/Europabrücke	1890	635200	5529365
28	Pödeldorfer Straße, Haltestelle Wörthstraße	1620	637654	5529433	100	Margartendamm 38, nahe Sendeanlage	5560	635003	5529497
29	Pödeldorfer Str. 142, Nordseite	30	637840	5529437	101	Hafenstraße/Regnitzstraße	7610	634719	5529740
30	Pödeldorfer Str. 142, Südseite	17060	637824	5529410	102	Lagerhausstraße	210	634556	5530102
31	Berliner Ring, Höhe Pödeldorfer Str. 144	4480	637900	5529380	103	Hafenstr. 28, Bayerischer Hafen	3200	634192	5530370
32	Schwimmbad Bambados, Vorgarten mit Bambus	1620	638074	5529315	104	Laubanger 29	160	634202	5530561
33	Schwimmbad Bambados, Parkplatz, Feldahorn	2540	638202	5529346	105	Heganger	1400	634341	5530812
34	Carl-Meinelt-Str.	5360	638043	5529094	106	Emil-Kemmer-Str. 2	5000	633822	5530863
35	Volkspark, FC Eintracht, Ostseite	120	638343	5529065	107	Emil-Kemmer-Str. 14	2500	634342	5531099
36	Michelsberger Garten, Teil Streuobst	5450	634831	5528673	108	Dr. Robert-Pfleger-Straße 60	90	634448	5530978
37	Michelsberger Garten, Terrassengarten, bei Eibe	2500	634988	5528508	109	Friedhof Gaustadt, Haupteingang	13100	632981	5529677
38	Michelsberger Garten, Südostecke, bei Holunder	910	635036	5528455	110	Friedhof Gaustadt, Ahornpaar	1400	632929	5529728
39	Michelsberg, Aussichtsterrasse, oberhalb Weinberg	1260	634924	5528463	111	Herzog-Max-Str. 21	1600	636245	5528071
40	Michelsberg, Aussichtsterrasse, Aussichtspunkt	780	634911	5528537	112	Gaustadter Hauptstr. 116	10	634042	5529457
41	Michelsberg, Nordostecke, bei jungen Linden	390	634874	5528565	113	Landesgartenschaugelände, Hafenerlebnispfad	2000	633789	5529894
42	Storchsgasse/Michelsberg	200	634725	5528415	114	Landesgartenschau, junge Baumgruppe	1270	633949	5529718
43	St. Getreu-Kirche, Südseite	55	634518	5528405	115	Würzburger Str.	340	635283	5527151
44	Villa Remeis, Garten	390	634295	5528203	116	Würzburger Straße/Arthur-Landgraf-Straße	1380	635355	5526862
45	Villa Remeis, Treppe	300	634400	5528237	117	Hohe-Kreuz-Straße/Würzburger Straße, Haltestelle	590	635383	5526733
46	Maienbrunnen 2	3920	634744	5528838	118	Hohe-Kreuz-Straße	10950	635469	5526729
47	Am Leinritt	2140	635071	5528617	119	Am Hahnenweg 6	3420	635332	5526729
48	Abtsberg 27	130	634526	5528935	120	Am Hahnenweg/Viktor-von-Scheffel-Straße	640	635307	5526710
49	Welcome Hotel, Garten	3200	634788	5529012	121	Am Hahnenweg 28 a	145	635028	5526654
50	Mußstraße, eingang Kindergarten	1670	634864	5529011	122	Schlüsselberger Straße	200	634712	5526534
51	Mußstraße/Schlüsselstraße	710	634846	5529034	123	Schlüsselberger Str./Haltestelle Hezilostr., Parkdeck	460	634749	5526549
52	Nebingerhof	2040	635069	5528901	124	Hezilostr. 13	70	634604	5526563
53	Graf-Stauffenberg-Platz	100	635120	5529009	125	Sückleinsweg, junge Hainbuchenhecke	75	634512	5526654
54	Don-Bosdo-Straße, Innenhof	10	635176	5529056	126	Rößleinsweg, oberes Ende	300	634708	5526789
55	Pfeuferstraße/Weide	1100	635222	5528820	127	Große Wiese	1500	634874	5526810

Table 3 (*continued*)

Number	Streets and parks in Bamberg and Hallstadt	Measurement μW/m²	X	Y	Number	Streets and parks in Bamberg and Hallstadt	Measurement μW/m²	X	Y
56	Weidendamm/Don-Bosco-Straße	1860	635166	5529195	128	Suidgerstraße	195	634508	5526409
57	Katzenberg/Karolinenstraße	1720	635316	5528239	129	Waizendorfer Straße	280	635317	5525864
58	Vorderer Bach	450	635305	5528141	130	Waizendorfer Straße, Einfahrt Gärtnerei	210	635326	5525582
59	Obere Brücke	8000	635565	5528289	131	Klinikum, Nähe Spielplatz	175	635732	5525672
60	Judenstraße	6	635479	5528040	132	Klinikum Weiher	100	635759	5525520
61	Tourist Information	4920	635674	5528172	133	Buger Straße/Bamberger Straße	2730	635829	5526082
62	Universität, Am Kranen 14, Innenhof	10	635501	5528535	134	Dunantstraße	470	635848	5526176
63	Fleischstraße	10	635703	5528683	135	Buger Straße/Paradiesweg	90	635743	5526286
64	ZOB	600	635882	5528541	136	Buger Straße/Abzweigung Münchner Ring	470	635528	5526499
65	Schönleinsplatz, Ostseite	900	636004	5528300	137	Hallstadt, Markplatz, bei Linde	2000	634582	5532426
66	Friedrichstraße, Parkplatz	165	635984	5528360	138	Hallstadt, Markplatz 21, Innenhof	8	634632	5532488
67	Franz-Ludwig-Straße/Luisenstraße	1720	636158	5528410	139	Hallstadt, Lichtenfelser Str. 12	4000	634659	5532474
68	Franz-Ludwig-Str, Strassenbauamt	90	636246	5528408	140	Hallstadt, Lichtenfelser Str. 8	9000	634720	5532516
69	Heiliggrabstraße, Nähe Sender	4740	636072	5529245	141	Hallstadt, Am Gründleinsbach/Kemmerner Weg	200	634743	5532784
70	Heiliggrabstr. 29, Landesjustizkasse	20	636063	5529399	142	Hallstadt, Valentinstraße/Seebachstraße	2200	634232	5532237
71	Heiliggrabstr. 57, Aussichtspunkt Schiefer Turm	4500	635797	5529410	143	Hallstadt, Johannisstr. 6	5000	634805	5532078
72	Bahnhof, ParkplatzWestseite	1600	636300	5529374	144	Hallstadt, Bamberger Straße/Michael-Bienlein-Straße	1860	634805	5531969

For each selected tree, the types of damage and the Universal Transversal Mercator (UTM) coordinates were recorded. In addition, two measurements were recorded: on the side showing damage and on the side without damage, generally corresponding to opposite sides of each tree. On both sides, the measurements were carried out at a variable height of 1–6 m (depending on the height of the tree), using a telescopic rod, a ladder, and the broadband radiofrequency meter.

Most measurements were done in the afternoon or in the evening on different days between April and October 2015. But the measurements on the two sides of each single tree were done one after another immediately on the same day and at the same time. The measurements took about 5 min on each side. When we stood on the ground or on a ladder we measured the peak values. When we used the telescopic rod we measured the peak hold values. Using the telescopic rod and measuring peak hold values it took longer, because the measurements had to be repeated often in cases where RF-EMF emitting cars or passengers disturbed the results. At each single tree the two measurements were done in the height where the damage had appeared. Because the height of the 120 trees differed, it was necessary to do the measurements at different heights.

In theory, although measurements are changing continuously there is no evidence about significant changes in power densities of electromagnetic radiation produced by phone masts over time. One study carried over one year in the city of Madrid showed no changes in terms of radiation intensity between the three rounds of measurements

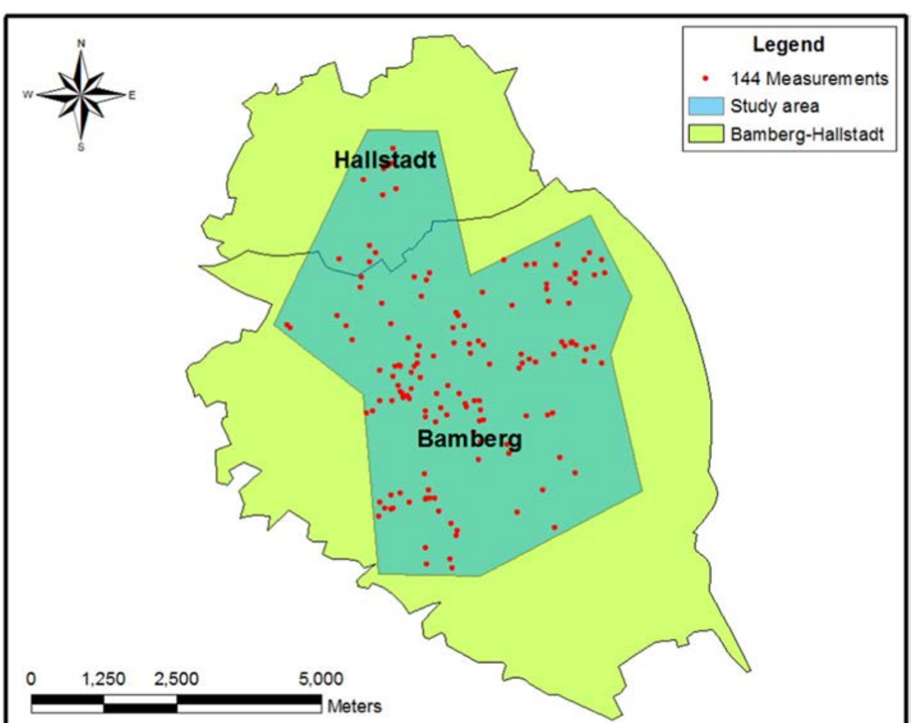


Fig. 2. Location of the 144 measurements points in Bamberg and Hallstadt in the study area.

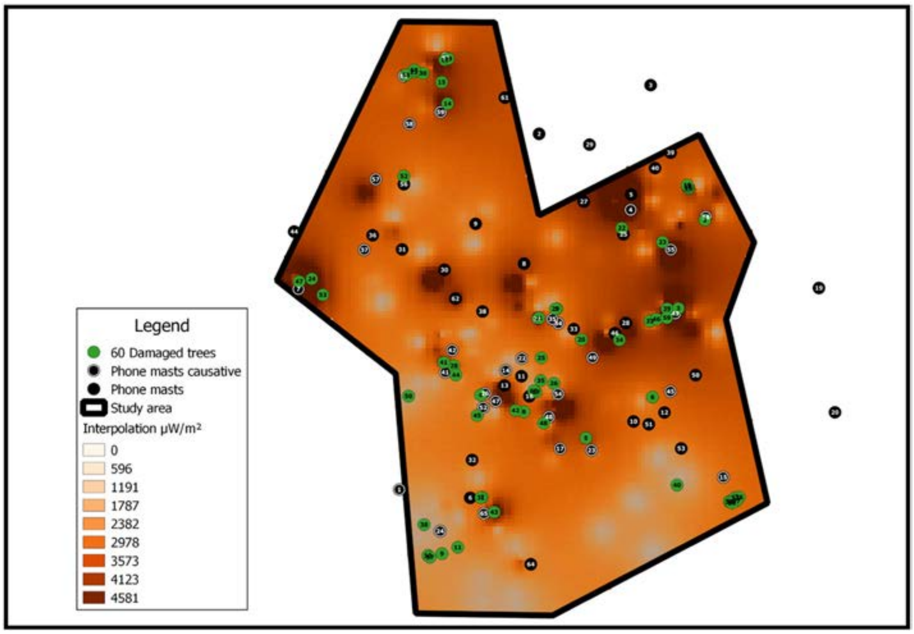


Fig. 3. Map showing the 60 damaged trees and phone masts (both with code numbers) over the interpolation electromagnetic map of the 144 measurement points.

performed in about 200 sampling points (own data). Repeatability analysis checked this. Despite the fact that the increase in sector antennas (observed between 2011 and 2015) would have probably increased the radiation in the environment of the study area, measurements used in this study were mostly done in 2015.

In an attempt to link the electromagnetic radiation measured at every tree to specific phone masts, the distances to the three nearest antennas that could be mainly responsible for the radiation measurements at each tree were calculated in meters with Geographical Information System (GIS) programs, following the general approach criteria of proximity. However, it must be taken into account that buildings and vegetation diminish radiation intensity and, in many cases, the nearest phone mast or masts may be obscured by obstacles. In other cases, the phone mast is in direct line of sight from the tree and the radiation can reach the tree directly.

Additionally, 30 random points were generated inside the polygonal study area and outside a layer of buildings, downloaded from: http://www.mapcruzin.com/free-germany-arcgis-maps-shapefiles.htm using a Random Points tool of QGIS 2.6.0-Brighton (QGIS Development Team, 2014) allowing create random points inside a specific layer. Therefore the points were randomly situated in specific places in the study area outside buildings but not frequently concur with the location of trees. That is why measurements were taken from the nearest tree for each random point, generating a random tree group. Measurements and damage characteristics were scored in the same way as with 60 damaged trees explained above, measuring the maximum value of radiation corresponding to opposite sides of each tree.

In areas of the city with low measurements of electromagnetic radiation (no visual contact to any phone mast and power flux density $<50\ \mu W/m^2$), we scored another 30 trees in the same way as with 60 damaged trees and 30 random points. The UTM coordinates and the three nearest phone masts of each tree in these last two groups (random and low radiation trees) were also recorded.

To generate electromagnetic maps, we used ArcGis 9.3 (ESRI, 2008) and QGIS 2.6.0-Brighton (QGIS Development Team, 2014). To check possible differences between groups of data and taking into account that there were two measures made in each tree, repeated measures analysis of variance were applied, considering a repeated measures factor (within-subjects) and another between-subjects. The post hoc Bonferroni test was used in all cases to elucidate significant differences. Statistics were performed using STATISTICA 7 program (StatSoft, Inc, 2004).

3. Results

The results of radiation measurements obtained at 144 points in Bamberg and Hallstadt at a height of 1.5 m were between 6 $\mu W/m^2$ (0.047 V/m) and 17,060 $\mu W/m^2$ (2.53 V/m) (for measurements and UTM coordinates, see Table 3). The measured values are far below the current limit values (41 V/m for GSM system and 61 V/m for UMTS; ICNIRP, 1998).

The locations of these points in the study area are shown in Fig. 2. By interpolation of the 144 measurements points (Table 3), we prepared a map of the power flux density in Bamberg and Hallstadt (Fig. 3). This map is theoretical and approximate, since many factors affect the true electromagnetic values. However, the map is useful to provide approximate differences in exposure (electromagnetic pollution) throughout the city.

The 60 selected trees showing damage patterns not attributable to diseases, pests or other environmental factors are presented in Table 4. In this Table, we added the tree code number, the scientific name, the UTM coordinates, the measurements (power flux density) on both sides of each tree, and the distances (meters) and code numbers to the three nearest antennas for each tree, which may be mainly responsible for the electromagnetic radiation measured. We also included the orientation of the tree damage and the number of main (nearest) phone mast(s) in direct line of sight, whose lobe of radiation most directly affected each tree. Finally, we included the codes of damage observed in the 60 trees.

From all 60 selected trees, one or more phone mast(s) could be seen, with no obstacles between the phone mast and damaged tree. In many cases, one of the three closest antennas caused the main radiation on the tree surface. In ten trees (codes: 4, 7, 9, 10, 15, 26, 27, 31, 35, and 50), another antenna in direct line of sight caused the measured radiofrequency exposure. This was determined using topography and existing buildings (Table 4 and Fig. 3).

The 60 damaged trees (with their code number) and the phone masts are overlaid on the electromagnetic map prepared by interpolation of the 144 measurements points (Fig. 3). The likely antenna or

antennas causing radiation damage to each tree are also shown (Fig. 3). The measurements at all selected trees revealed significant differences between the damaged side facing a phone mast and the intact (or less damaged) opposite side. On the side facing a phone mast, the measured values were 80–13,000 μW/m² (0.173–2.213 V/m). On the opposite side the values were 8–720 μW/m² (0.054–0.52 V/m).

Table 4
60 selected trees showing damage patterns not attributable to diseases, drought or other environmental factors.

														Effect codes												
														1	2	3	4	5	6	7	8	9	10	11	12	13
N°	Scientific name	X	Y	Side antenna measurement μW/m²	Opposite side measurement μW/m²	Number of Phone Mast 1	Distance a 1	Number of Phone Mast 2	Distance a 2	Number of Phone Mast 3	Distance a 3	Direction of damage	Number of main phone mast(s) causing the radiation	Damage only on one side	Sparse leaves or needles (crown transparency)	Brown leaves (start at leaf margins)	Colour change of leaves prematurely	leaves fall prematurely	Dead branches (Peak branches dried).	Tip of the main guide dried	Irregular growth	Not grow in eight	Color change of needles	Dead parts were trimmed down	damage on different sides	no damage
1	*Acer platanoides*	636298	5529366	970	130	35	145,6	34	190,1	21	274,6	S, SW	35,34,21	+	+	+		+	+	+		+				
2	*Acer platanoides*	638211	5530518	680	80	18	41,76	55	583,9	40	930,8	N	18	+	+	+		+	+			+		+		
3	*Acer platanoides*	637868	5529371	2100	290	43	77,18	28	703,9	55	768	S	43	+	+	+		+	+	+		+				
4	*Acer platanoides*	635316	5528245	2300	130	26	61,68	52	164,6	47	210,4	E, S	26,52,47, 14	+	+	+		+	+	+		+		+		
5	*Acer platanoides*	636677	5527688	3600	290	23	174,1	17	363,2	48	552,2	S	23	+	+	+		+	+	+		+		+		
6	*Acer platanoides*	637536	5528219	700	140	45	242,3	12	251	51	356,4	E	45	+	+	+		+	+	+						
7	*Acer platanoides*	635339	5526919	270	30	6	156,2	65	211	32	502,6	W	1	+		+		+	+	+		+		+		
8	*Acer platanoides*	635876	5528029	80	10	16	211,6	48	328,1	47	389,9	W	47	+	+	+		+								
9	*Acer platanoides*	634819	5526187	160	20	24	294,1	65	751,1	6	811,2	N	24, 1		+	+		+	+					+		
10	*Acer platanoides*	634638	5526163	180	55	24	353,3	65	904,4	6	926,3	N	24, 1		+	+		+	+							
11	*Acer platanoides*	635022	5526270	95	20	24	310	65	553,4	6	661,9	NW	24	+	+			+								
12	*Acer platanoides*	634854	5532596	11800	400	60	26,93	63	568,2	59	680,1	N	60	+	+	+		+	+	+		+				
13	*Acer platanoides*	634455	5532438	9900	620	63	139,1	60	448,1	59	624	W	63	+			+							+		
14	*Acer platanoides*	634890	5532028	3380	500	59	142,1	58	557,5	60	593,6	SW	59	+	+	+		+	+	+		+		+		
15	*Acer platanoides*	634815	5532307	1050	50	60	317,8	59	389,3	63	495,3	SW	58	+	+	+		+	+	+		+		+		
16	*Carpinus betulus*	638001	5530928	1210	120	18	431,5	40	506,6	39	518,8	S	18	+	+	+		+	+							
17	*Carpinus betulus*	637996	5530945	2520	150	18	448,7	40	493,7	39	501,3	S	18	+	+	+		+	+							
18	*Carpinus betulus*	637987	5530959	890	90	18	465,3	40	478,9	39	484,8	S	18	+	+	+		+								
19	*Carpinus betulus*	637984	5530970	670	10	40	471,1	39	473,6	18	476,3	S	18	+	+	+		+								
20	*Carpinus betulus*	636619	5528966	1000	200	33	169,6	49	274,2	34	367,6	SE	49		+	+		+	+			+		+		
21	*Carpinus betulus*	636068	5529245	430	20	21	14,87	35	173,5	34	259,1	W	21	+	+	+		+				+		+		
22	*Carpinus betulus*	637138	5530413	4340	110	25	83,24	4	263,4	5	450,6	NE	4	+	+	+		+	+	+		+				
23	*Carpinus betulus*	637664	5530231	990	60	55	145,8	25	513,2	4	586,9	E	55	+	+	+		+	+							
24	*Carpinus betulus*	633137	5529754	2700	50	7	217,4	44	653,7	37	776,2	E	37	+	+	+		+	+							
25	*Tilia sp.*	636098	5528729	870	150	22	249,1	11	349,5	14	486,5	W	22	+	+	+		+	+							
26	*Tilia sp.*	636261	5528398	410	20	54	149,5	16	358,4	11	428	W	14	+		+		+								
27	*Tilia sp.*	636030	5528283	680	160	16	100,7	11	279	54	287	S	48	+	+		+	+	+					+		
28	*Tilia sp.*	634972	5528626	660	170	41	139,8	42	202,3	26	539,6	SW	41	+	+	+		+	+	+		+		+		
29	*Tilia sp.*	636283	5529365	2450	160	35	139,5	34	191,2	21	260,9	SW	35, 34, 21	+		+		+				+		+		
30	*Tilia sp.*	634573	5532422	3800	420	63	249,6	60	352,5	59	552,8	NE	60	+	+	+		+	+					+		
31	*Tilia sp.*	635319	5526914	380	120	6	136	65	208,9	32	502,6	W	1	+	+		+	+	+	+						
32	*Quercus robur*	638598	5526911	860	130	15	308	53	944,7	12	1434	NW	15		+			+	+							
33	*Quercus rubra*	637501	5529207	1340	120	28	312	43	341,4	46	478,8	E	43	+	+			+	+							
34	*Quercus rubra*	637107	5528961	1650	250	46	105,4	28	236,1	49	414,1	SW	49	+	+				+							
35	*Aesculus hippocastanum*	636092	5528434	400	20	16	252,3	11	255,2	54	284,3	W	14	+	+	+		+	+	+		+				
36	*Robinia pseudoacacia*	638653	5526920	1300	40	15	331,1	53	979,9	12	1463	NW	15	+			+		+	+		+				

Table 4 *(continued)*

37	*Robinia pseudoacacia*	638619	5526874	660	240	15	350,5	53	985,3	12	1476	NW	15	+			+		+					+		
38	*Sorbus occuparia*	634587	5526564	84	8	24	223,4	1	555,7	6	690,2	N	1	+	+	+		+	+	+		+				
39	*Acer negundo*	637722	5529366	3060	310	43	122,3	28	562,9	46	743,9	SE	43	+	+			+	+			+		+		
40	*Acer saccharinum*	637852	5527078	840	180	53	477,9	15	604,7	51	868,4	E	15	+	+			+								
41	*Juglans regia*	634841	5528669	4500	590	41	129,6	42	191,4	26	668,2	N, E	42	+	+			+	+	+	+	+				
42	*Taxus baccata*	635767	5528046	300	70	16	255,3	47	282,7	13	354,2	NW	47	+	+				+				+	+		
43	*Taxus baccata*	635491	5526727	8970	190	65	133,2	6	359,3	32	734,2	W	65	+	+				+				+	+		
44	*Taxus baccata*	634997	5528506	2500	240	41	140,4	42	324,6	26	446,9	N,E,W	41,42		+				+				+	+		
45	*Taxus baccata*	635272	5527980	2700	70	52	130	47	302,8	26	303,6	NE	52	+	+				+				+	+		
46	*Taxus baccata*	637586	5529231	1520	190	43	253,1	28	399	46	567	E	43	+	+								+	+		
47	*Thuja occidentalis*	632975	5529719	910	30	7	98,51	44	651,3	37	936,1	S	7	+	+				+				+			
48	*Thuja occidentalis*	636128	5527881	120	10	48	105,6	16	393,2	17	393,6	S	17	+	+				+				+			
49	*Thuja occidentalis*	634900	5532611	13000	520	60	37,36	63	616,5	59	700,2	NW	60	+	+				+				+			
50	*Thuja occidentalis*	634387	5528232	290	50	41	565,8	42	818,5	52	974,3	S	1	+	+				+	+			+			
51	*Picea pungens*	638525	5526863	770	90	15	326,2	53	927,6	12	1427	NE	15	+	+				+				+			
52	*Picea pungens*	634328	5531086	3080	310	56	104	57	367,3	58	681,7	W	57		+				+			+	+			
53	*Picea pungens*	633280	5529546	1350	200	7	323,8	37	792,7	44	900,5	W	7	+	+				+		+		+			
54	*Pinus sylvestris*	638542	5526861	790	50	15	332,6	53	940,5	12	1439	NE	15		+				+		+	+	+			
55	*Pinus sylvestris*	634461	5532462	5300	130	63	154,9	60	433,2	59	641	SW	63	+	+								+			
56	*Pseudotsuga menziesii*	638560	5526844	1720	60	15	354,2	53	965,2	12	1463	NE	15	+	+				+	+		+	+			
57	*Juniperus communis*	634664	5526141	160	20	24	363,1	65	897,6	6	929,4	N	24	+	+				+				+			
58	*Corylus avellana 'Contorta'*	634355	5532399	420	80	63	31,78	60	555,3	58	636,5	W	63	+	+	+		+	+							
59	*Corylus avellana*	637720	5529249	3880	720	43	121,7	28	534,2	46	700,2	N	43	+	+	+		+						+		
60	*Symphoricarpos albus*	636002	5528299	1200	320	16	90,27	11	248,5	54	316,5	E	54	+	+			+	+					+		

In the five most represented species ($n \geq 4$) among the 60 affected trees, most trees showed damage only on one side: unilateral damage (Damage code 1, Tables 2 and 4). By species and percentages: *Acer platanoides* (86%), *Carpinus betulus* (88%), *Tilia* sp. (100%), *Taxus baccata* (80%) and *Thuja occidentalis* (100%). On the seven trees not given code 1, the damage spread over the whole tree, but trees still showed side differences. Most of these trees were characterized with sparse leaves or needles (crown transparency) (Damage code 2, Tables 2 and 4). By species and percentages: *Acer platanoides* (86%), *Carpinus betulus* (100%), *Taxus baccata* (100%) and *Thuja occidentalis* (100%). In many of the trees with the one-sided damage, the leaves turned prematurely yellow or brown in June – this always began at the leaf margins (Damage code 3, Tables 2 and 4). The species with higher percentages were: *Acer platanoides* (86%) and *Carpinus betulus* (100%). In many trees leaves fall prematurely: *Acer platanoides* (93%), *Carpinus betulus* (100%) and *Tilia sp.* (100%) (Damage code 5, Tables 2 and 4). Many trees of the species *Acer platanoides* (80%), *Taxus baccata* (80%) and *Thuja occidentalis* (100%) had dead branches (Peak branches dried) (Damage code 6, Tables 2 and 4). All the trees of the species *Taxus baccata* (100%) and *Thuja occidentalis (100%)* exhibited color change of the needles (Damage code 10, Tables 2 and 4). Finally, in all trees of the species *Taxus baccata*, dead parts were trimmed (Damage code 11, Tables 2 and 4). Some trees stopped growing in height while, in others, the main guide died (see Tables 2 and 4).

The 30 randomly selected trees are presented in Table 5 with the tree code number, the scientific name, the UTM coordinates, the measurements (power flux density) on both sides of each tree, the distance (meters) to the three nearest antennas, their code number and the damage codes. Trees in these locations may be in areas with either high or low radiation. Seventeen trees in this group were situated in places with low radiation and showed no signs of damage. The measurements were 8–50 μW/m^2 (0.054–0.137 V/m) and showed no difference between the two opposite sides. Thirteen trees stood in the radiation field of one or more phone mast. Six of these had damage only on the side facing a phone mast, and five had damages on other sides. The measurements on the exposed sides were 40–4600 μW/m^2 (0.122–1.316 V/m).

The 30 trees selected in areas with low radiation (radio shadow of hills, buildings or trees) are presented in Table 6 with the tree code number, scientific name, UTM coordinates, measurements (power flux density) on both sides of each tree, distance (meters) to the three nearest antennas, their code number and the damage codes. All trees selected in low radiation areas showed no damage (code 13). The power flux density values measured were 3–40 μW/m^2 (0.033–0.122 V/m) and no significant differences were found between the two opposite sides.

The trees in random points and the trees in areas of low radiation are represented In Fig. 4 over the electromagnetic map prepared by interpolation of the 144 measurements points.

We performed a Repeated Measures ANOVA analysis in order to include the measurements of the exposed and shielded side of each tree (R1 = within subjects factor) in the three groups of trees (damaged, random, and low radiation), and to avoid pseudoreplication. The comparisons of all factor levels revealed significant differences, including the interaction between factors. A post hoc Bonferroni comparisons test, recommended for different sized groups of samples, revealed significant differences between measurements from the exposed side of damaged trees and all other groups (Table 7). Fig. 5 shows the measurements (mean and standard error) in all groups.

In the "Random points" group of trees, we performed another Repeated Measures ANOVA (R1 = within subjects factor) for trees damaged and undamaged within this group (Table 8). The results showed significant differences in both factors, including the interaction, which means that depending on the group of tree (damaged or undamaged),

Table 5
Results of the tree measurements at the 30 random points.

												Effect codes												
												1	2	3	4	5	6	7	8	9	10	11	12	13
N°	Scientific name	X	Y	Side antenna measurement µW/m²	Opposite side measurement µW/m²	Number of Phone Mast 1	Distance a 1	Number of Phone Mast 2	Distance a 2	Number of Phone Mast 3	Distance a 3	Damage only on one side	Sparse leaves or needles (crown transparency)	Brown leaves (start at leaf margins)	Colour change of leaves prematurely	leaves fall prematurely	Dead branches (Peak branches dried).	Tip of the main guide dried	Irregular growth	Not grow in eight	Color change of needles	Dead parts were trimmed down	damage on different sides	no damage
1	*Salix viminalis*	634095	5532455	10	10	63	241,1	58	754,9	60	786,7													+
2	*Thuja occidentalis*	634760	5532680	500	120	60	119,6	63	524,2	59	763		+				+	+			+		+	
3	*Abies alba*	634030	5530490	2200	900	36	201,2	37	418,8	31	447,7		+				+			+	+		+	
4	*Acer campestre*	634545	5530739	890	320	56	326,5	31	649,4	57	657,5	+	+				+							
5	*Acer platanoides*	634557	5530005	4600	1100	31	284,9	30	322,2	62	668,1	+	+	+		+						+		
6	*Picea abies*	635311	5530644	1900	210	9	185,6	8	894,8	30	900									+	+			
7	*Thuja occidentalis*	635635	5529879	10	10	8	252,5	38	621,9	9	702,6													+
8	*Acer platanoides*	635693	5529848	2600	310	8	210,9	38	625,5	21	707,1	+	+			+	+					+		
9	*Cornus sanguinea*	636415	5530248	40	30	27	559,3	8	614,5	25	750,8													+
10	*Acer pseudoplatanus*	637525	5530896	50	50	5	270,5	40	298,1	4	366,7													+
11	*Syringa*	638111	5531436	10	10	39	344,8	40	595,7	18	885,1													+
12	*Acer platanoides 'Globorum'*	637928	5530541	30	30	18	295,5	55	436,8	4	683,7													+
13	*Acer platanoides*	637159	5529361	20	15	28	181,7	46	330,8	43	671,3													+
14	*Quercus rubra*	638342	5528994	1480	570	50	549,7	43	600,8	45	907,4		+			+	+					+	+	
15	*Thuja occidentalis*	638359	5528569	25	20	50	275,5	45	653,6	12	866,2													+
16	*Tilia sp*	637412	5527922	460	320	51	93,6	10	122,5	12	293,8											+		
17	*Quercus robur*	637363	5527807	45	33	10	120	51	137,3	12	389,4													+
18	*Larix decidua*	637804	5527628	4400	3170	53	125,8	51	396,4	12	408,5		+				+		+				+	
19	*Acer pseudoplatanus*	637919	5527135	760	120	53	418,2	15	530,9	51	849,1	+	+			+	+	+				+		
20	*Acer negundo*	637329	5526888	190	30	23	865,1	53	879,8	51	990,7	+										+		
21	*Quercus robur*	637115	5527423	46	26	23	382	10	511,2	51	578,5													+
22	*Thuja occidentalis*	637315	5526260	40	13	64	1367	23	1390	53	1421	+									+			
23	*Salix matsudana 'Tortuosa'*	635403	5525413	15	12	64	848,8	24	1229	65	1297													+
24	*Populus tremula*	635410	5525828	15	9	64	596,8	65	882,5	24	897													+
25	*Salix matsudana 'Tortuosa'*	634981	5526161	41	23	24	369,8	65	665,7	6	777,7													+
26	*Prunus sp.*	634829	5526050	28	21	24	431,4	65	845,7	6	931,9													+
27	*Picea pungens*	634791	5526809	470	340	24	329	6	405,3	1	563,6		+				+		+				+	
28	*Cornus sanguinea*	635164	5527863	15	15	52	288,9	26	454,4	47	460,7													+
29	*Cornus sanguinea*	634905	5528779	20	20	42	65,12	41	242	26	695,1													+
30	*Acer negundo*	634202	5529092	8	8	42	792,6	41	859	62	886,9													+

significant or non-significant respectively differences between the measurements of the two sides are seen (Fig. 6). A post hoc Bonferroni comparisons test showed significant differences between the measurements from the exposed side of damaged trees and all other groups in the random points group (Table 8).

Of the 120 trees, those with lower mean distance to the three closest antennas have usually higher values of radiation (Fig. 7). However, screening is common in cities due to a large amount of buildings, thus some trees that are close to antennas show lower radiation values than expected. This means that radiation measurements at points close to antennas are variable (high and low) while trees farther from antennas always have low values.

A dossier with documentation gathered over the years and the examples of tree damages is presented in: http://kompetenzinitiative.net/KIT/KIT/baeume-in-bamberg/

4. Discussion

In the present study it was useful, that tree damages in the vicinity of phone masts in Bamberg and Hallstadt had been documented starting 2006. We found a high level of damage to trees in the vicinity of phone masts. The damage encountered in these trees is not attributable to harmful organisms, such as diseases, pests or other environmental factors. These would impact upon the entire tree, whereas damage to trees in the present study was only found on parts of the tree and only on one side (unilateral). Therefore, these factors cannot explain the damage documented here. Generally in all trees of this study, damage is higher in areas of high radiation and occurs on the side where the nearest phone mast is located (Table 4 and Fig. 3). Moreover, areas with more antennas have more levels of radiation and damaged trees are found most often in these high electromagnetic polluted areas. These results showed that side differences in damage corresponded to side differences in measured values of power flux density. This paper look at the effects on trees, but also provides information on how electromagnetic radiation is distributed in a city (interpolation map and Fig. 7).

In this study deciduous and coniferous trees were examined under the real radiofrequency field conditions around phone masts in Bamberg and Hallstadt. From most phone masts a broad band of frequencies with different modulations and pulse frequencies and fluctuating power densities is emitted (GSM 900, GSM 1800, UMTS, LTE, TETRA). Different signals may have different effects due to their physical parameters (Belyaev, 2010; IARC, 2013). We do not discriminate between these different signals and cannot answer the question which part of the

Table 6
Results of the tree measurements in the 30 points with low radiation.

Nº	Scientific name	X	Y	Side antenna measurement µW/m²	Opposite side measurement µW/m²	Number of Phone Mast 1	Distance a 1	Number of Phone Mast 2	Distance a 2	Number of Phone Mast 3	Distance a 3	Effect codes												
												1	2	3	4	5	6	7	8	9	10	11	12	13
												Damage only on one side	Sparse leaves or needles (crown transparency)	Brown leaves (start at leaf margins)	Colour change of leaves prematurely	leaves fall prematurely	Dead branches (Peak branches dried).	Tip of the main guide dried	Irregular growth	Not grow in eight	Color change of needles	Dead parts were trimmed down	damage on different sides	no damage
1	*Acer platanoides*	636741	5529855	26	20	25	636,3	33	784,1	35	798,8													+
2	*Carpinus betulus*	634853	5529041	10	8	42	234,5	62	476,4	41	500,1													+
3	*Carpinus betulus*	638311	5528439	12	10	50	229,7	45	563,5	12	750													+
4	*Carpinus betulus*	636753	5529880	8	8	25	609,6	33	811,5	28	823,5													+
5	*Carpinus betulus*	637817	5527130	15	12	53	432,1	15	633	51	806,6													+
6	*Carpinus betulus*	634931	5526731	15	15	24	286	6	310,3	65	428,6													+
7	*Tilia sp.*	636500	5529673	8	8	35	511,4	34	528,3	33	570,3													+
8	*Tilia sp.*	636824	5529794	17	9	25	635,7	28	713,1	33	755,3													+
9	*Quercus robur*	636455	5526130	9	8	64	497,5	65	1240	17	1425													+
10	*Quercus robur 'Fastigiata'*	636178	5528932	10	10	34	282,2	35	306,5	21	332													+
11	*Aesculus hippocastanum*	636828	5529780	10	10	25	645,5	28	699	33	744,2													+
12	*Aesculus carnea*	636463	5529709	12	12	35	526,1	34	551,4	33	608,6													+
13	*Robinia pseudoacacia*	635507	5528534	15	15	14	136,6	13	201,5	26	299,2													+
14	*Robinia pseudoacacia*	634720	5532783	8	8	60	216,7	63	559,3	59	868,7													+
15	*Acer campestre*	635697	5528689	40	30	14	136,5	22	155,8	11	246,8													+
16	*Acer campestre*	636486	5526116	6	6	64	526,2	65	1273	23	1437													+
17	*Juglans regia*	635744	5528667	20	15	22	119	14	145,7	11	202,8													+
18	*Platanus hispanica*	635496	5528529	17	15	14	148,4	13	204,1	26	289,9													+
19	*Prunus avium*	637958	5530874	10	8	18	412,4	40	502,6	39	551,4													+
20	*Prunus sp.*	636079	5528463	10	10	11	237,5	16	269,7	54	312,7													+
21	*Taxus baccata*	638407	5528502	5	5	50	316	45	673,6	12	864,8													+
22	*Taxus baccata*	638222	5531032	10	10	18	474	39	578,6	40	673,1													+
23	*Thuja occidentalis*	636518	5529853	9	9	8	648,4	35	680	34	705													+
24	*Thuja occidentalis*	635318	5528784	20	15	42	371,5	14	389,4	13	514,8													+
25	*Picea pungens*	636512	5529735	17	17	35	571,4	34	590,8	33	632													+
26	*Juniperus communis*	636549	5529756	8	8	35	607,8	34	623,4	33	653,7													+
27	*Cornus sanguinea*	638167	5529098	8	6	43	397,2	50	597,9	45	899,8													+
28	*Sambucus nigra*	635529	5525601	5	5	64	625,2	65	1121	24	1146													+
29	*Corylus avellana*	636422	5526181	5	3	64	476,4	65	1187	17	1371													+
30	*Corylus avellana*	636625	5529834	6	6	35	714	34	725,2	25	732,3													+

radiation has caused the damage. Nevertheless broad bands of frequencies, modulation, pulse frequencies, interferences and other physical characteristics may play an important role, since in some cases, damage already appears at low intensities. This can be a shortcoming of the study.

The aim of the present study was to find out whether there is a causal relationship between the unilateral tree damages, which had been observed since 2006, and the RF-EMF emitted from phone masts and a preliminary observation to find out whether various species react differently to RF exposure.

The selection of the 60 unilaterally damaged trees was limited by the fact that we could do measurements only up to a height of 6 m. Trees with damages above the height of 6 m could not be included.

Many factors can affect the health of trees: Air and soil pollutants, heat, frost, drought, as well as composition, compaction and sealing of the soil, road salts, root injury due to construction work, diseases and pests. Most of these factors do not affect a tree only on one side over a period of >5 years. Industrial air pollutants could eventually cause unilateral damage in direction to an industrial emitter. But the observed unilateral damages appeared in all directions and were not oriented to the incineration plant or other industrial plants. Root injury due to construction work can produce damage on one side of a tree, but 24 of the 60 selected trees were situated in gardens, parks or on the cemetery where they could not be affected by construction damages.

From the damaged side there was always visual contact to one or more phone mast (s). In each case measurements of the power flux density on the damaged side which was facing a phone mast and on the opposite side without (or with less) damage were carried out and the difference between the measured values on both sides was significant (Fig. 5), as well as between the exposed side of damaged trees and all other groups. In all 60 trees the gradient of damage corresponded to a gradient of measured values. The attenuation of the RF-EMF within the treetop offers an explanation: a part of the RF-EMF is absorbed by leaves or needles and another part is reflected, scattered and diffracted.

In the randomely selected group of 30 trees, 17 trees were situated on places with low radiation. These 17 trees showed no damages, the measured values were below 50 µW/m^2 (0.137 V/m) and there was no difference between opposite sides as in the low radiation group. On the other hand, 13 trees grew in the radiation field of one or more phone mast (s). These trees showed unilateral damage or damage on different sides. The measured values at damaged trees showed differences between both sides as in the previous group above.

In the group of 30 trees in areas with low radiation (radio shadow of hills, buildings or trees and without visual contact to phone masts)

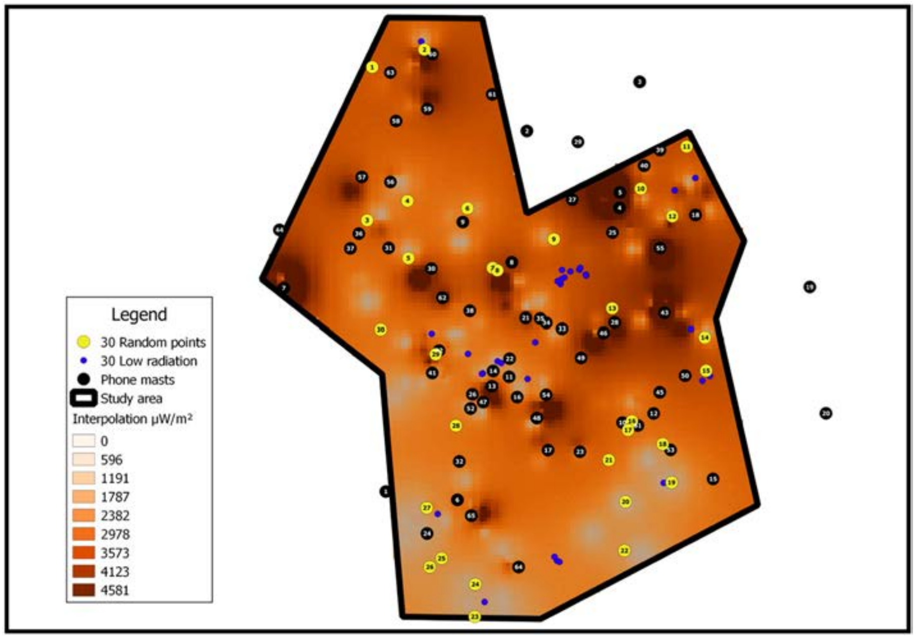


Fig. 4. Map showing the 30 trees at random points and the 30 trees in areas of low radiation (both with code numbers) over the interpolation electromagnetic map of the 144 measurement points. Phone masts (with code numbers) are also represented.

there were no unilateral damages. The measured values were below 50 µW/m^2 (0.137 V/m) and there was no difference between opposite sides. These results in the three groups point to a connection between unilateral tree damage and RF exposure.

In the electromagnetic field of all mobile phone base stations visited numerous tree damages were observed. The damage occurred in temporal relation with the putting into operation of new mobile phone base stations. Woody plants of all species are affected (deciduous and coniferous trees as well as shrubs).

In the five most represented species (n ≥ 4) among the 60 damaged trees (*Acer platanoides*, *Carpinus betulus*, *Tilia* sp., *Taxus baccata* and *Thuja occidentalis*), most trees showed damage only on one side (Damage code 1, Tables 2 and 4). Most of these trees were characterized with sparse leaves or needles (crown transparency) (Damage code 2, Tables 2 and 4). In many of the trees with the one-sided damage, the leaves turned prematurely yellow or brown in June – this always began at the leaf margins (Damage code 3, Tables 2 and 4). In many trees leaves fall prematurely (Damage code 5, Tables 2 and 4) or had dead branches (Peak branches dried) (Damage code 6, Tables 2 and 4). Some trees stopped growing in height while, in others, the main guide died (see Tables 2 and 4).

The differences in susceptibility of different species could be related to radiofrequency energy absorption properties of the trees (e.g., dielectric property). Perhaps this study cannot answer questions about these differences, however it is quite possible that differences are related to the electrical conductivity, related also with the density of the wood (species of fast or slow growth) and particularly with the percentage of water in the tissues. Poplars and aspen that grow near rivers and water bodies in Spain seem to be particularly sensitive to the effects of radiation. But the waves reflection in the water could also influence.

The results presented here lead us to conclude that damage found in the selected trees is caused by electromagnetic radiation from phone

Table 7
Repeated measures ANOVA analysis and Bonferroni post hoc comparisons (p < 0.01 values with *) in the three types of trees (damaged, random, and low radiation). Measurement Side 1/2 correspond to the maximum/minumum value of radiation respectively for the opposite sides of each tree.

	SS	Degr. of	MS	F	p
Intercept	62663309	1	62663309	25.81460	0.000001*
Type of tree	52931692	2	26465846	10.90280	0.000046*
Error	284010086	117	2427437		
R1	33197069	1	33197069	18.28694	0.000039*
R1*Type of tree	44608664	2	22304332	12.28656	0.000014*
Error	212395158	117	1815343		

	Type of tree	R1	{1}	{2}	{3}	{4}	{5}	{6}
1	Damaged	Measurement Side1		0.000000*	0.001829*	0.000001*	0.000000*	0.000000*
2	Damaged	Measurement Side2	0.000000*		1.000000	1.000000	1.000000	1.000000
3	Random	Measurement Side1	0.001829*	1.000000		1.000000	1.000000	1.000000
4	Random	Measurement Side2	0.000001*	1.000000	1.000000		1.000000	1.000000
5	Low radiation	Measurement Side1	0.000000*	1.000000	1.000000	1.000000		1.000000
6	Low radiation	Measurement Side2	0.000000*	1.000000	1.000000	1.000000	1.000000	

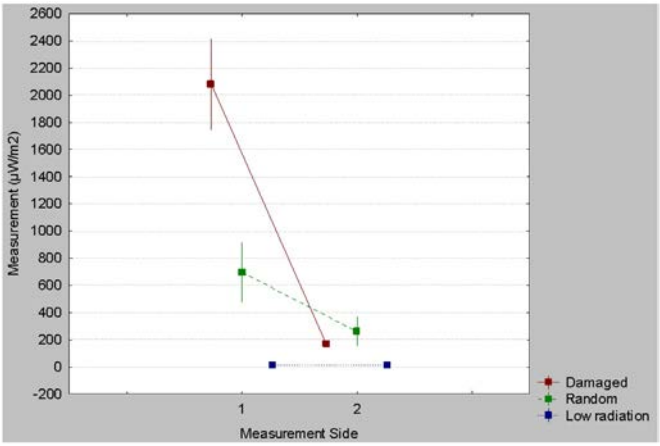


Fig. 5. Differences between measurements in both sides for the three different tree groups: damaged, random, and low radiation. Measurement Side 1/2 correspond to the maximum/minumum value of radiation respectively for the opposite sides of each tree. The bars represent means ± standard errors. The central point represents the mean and the straight line ± 0.95*SE.

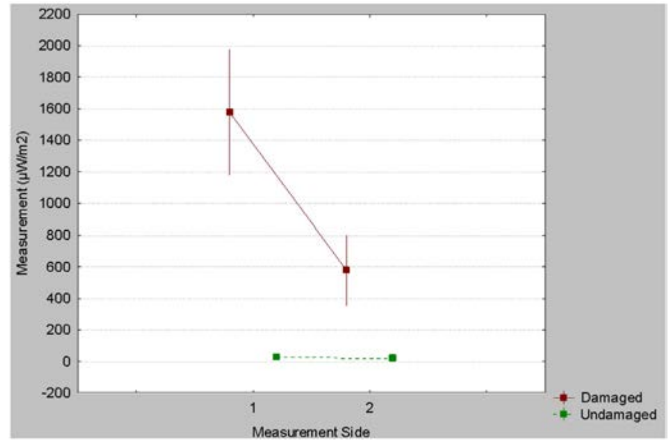


Fig. 6. Differences between measurements in both sides for the damaged and undamaged trees within the random trees group. Measurement side 1/2 correspond to the maximum/minumum value of radiation respectively for the opposite sides of each tree. The bars represent means ± standard errors. The central point represents the mean and the straight line ± 0.95*SE.

masts, as we proposed in previous studies (Balmori, 2004; Waldmann-Selsam, 2007; Waldmann-Selsam and Eger, 2013; Balmori, 2014). Interested parties are able to locate the damaged trees found in this work in Bamberg and Hallstadt with their UTM coordinates. However, trees with code numbers 20, 38 and 48 (Table 4) have been cut down and removed.

Research on the effects of radiation from phone masts is advancing rapidly. In February 2011 the first symposium on the effects of electromagnetic radiation on trees took place in Baarn, Netherlands (Schorpp, 2011 - http://www.boomaantastingen.nl/), where similar effects and results to those found in the current paper were presented.

Although there are some related experiments that show no effect of long-term exposure (3,5 years), 2450-MHz (continous wave) and power flux densities from 0.007 to 300 W/m^2 on crown transparency, height growth and photosynthesis of young spruce and beech trees (Schmutz et al., 1996), this result may not be transferred to modulated 2450-MHz or to other pulsed and modulated frequencies. In addiction, an increasing number of studies have highlighted biological responses and modifications at the molecular and whole plant level after exposure to high frequency electromagnetic fields (Vian et al., 2016). Plants can perceive and respond to various kinds of electromagnetic radiation over a wide range of frequencies. Moreover, a low electric field intensity (5 V/m) was sufficient to evoke morphological responses (Grémiaux et al., 2016). Electromagnetic radiation impacts at physiological and ecological levels (Cammaerts and Johansson, 2015), and evokes a multitude of responses in plants. The effects of high frequency electromagnetic fields can also take place at the subcellular level: it can alter the activity of several enzymes, including those of reactive oxygen species (ROS) metabolism, a well-known marker of plant responses to various kinds of environmental factors; it evokes the expression of specific genes previously implicated in plant responses to wounding (gene expression modifications), and modifies the growth of the whole plants (Vian et al., 2016). It could be hypothesized that membrane potential variations in response to electromagnetic radiation exposure may initiate electrical waves of depolarization (AP and/or VP) that could initiate immediate or delayed growth responses (Grémiaux et al., 2016). It has been proposed that electromagnetic fields act similarly in plants and in animals, with the probable activation of calcium channels via their voltage sensor (Pall, 2016).

Electromagnetic radiation (1800 MHz) interferes with carbohydrate metabolism and inhibits the growth of *Zea mays* (Kumar et al., 2015). Furthermore, cell phone electromagnetic radiation inhibits root growth of the mung bean (*Vigna radiata*) by inducing ROS-generated oxidative stress despite increased activities of antioxidant enzymes (Sharma et al., 2009). Germination rate and embryonic stem length of *Triticum aestivum* was also affected by cell phone radiation (Hussein and El-Maghraby, 2014). After soybeans were exposed to weak microwave radiation from the GSM 900 mobile phone and base station, growth of

Table 8
Repeated measures ANOVA analysis and Bonferroni post hoc comparisons (p < 0.01 values with *) in the random trees group. Measurement Side 1/2 correspond to the maximum/minumum value of radiation respectively for the opposite sides of each tree.

	SS	Degr. of	MS	F	p
Intercept	17829607	1	17829607	16.60985	0.000343*
13 code	16391606	1	16391606	15.27023	0.000538*
Error	30056202	28	1073436		
R1	3701923	1	3701923	16.73250	0.000329*
R1*13 code	3627579	1	3627579	16.39647	0.000368*
Error	6194761	28	221241		

	13 code	R1	{1}	{2}	{3}	{4}
1	Undamaged	Measurement Side 1		1.000000	0.002129*	0.416303
2	Undamaged	Measurement Side 2	1.000000		0.000034*	0.927155
3	Damaged	Measurement Side 1	0.002129*	0.000034*		0.000055*
4	Damaged	Measurement Side 2	0.416303	0.927155	0.000055*	

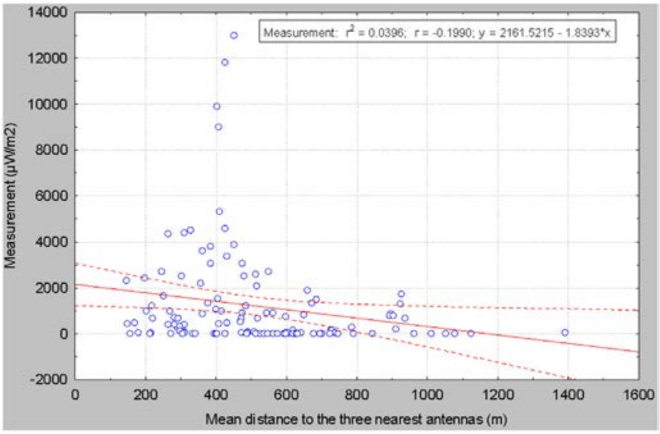


Fig. 7. Scatterplot showing the correlation between measurements from each of the 120 trees and the mean distance to the three nearest antennas. Dashed lines represent the 0.95 confidence interval.

epicotyl and hypocotyl was reduced, whereas the outgrowth of roots was stimulated. These findings indicate that the observed effects were significantly dependent on field strength as well as amplitude modulation of the applied field (Halgamuge et al., 2015). Phone mast radiation also affects common cress (*Lepidium sativum*) seed germination (Cammaerts and Johansson, 2015). In *Arabidopsis thaliana*, the long term exposure to non ionizing radiation causes a reduction in the number of chloroplasts as well as the decrease of stroma thylakoids and the photosynthetic pigments (Stefi et al., 2016). Finally, low-intensity exposure to radiofrequency fields can induce mitotic aberrations in root meristematic cells of *Allium cepa*; the observed effects were markedly dependent on the frequencies applied as well as on field strength and modulation (Tkalec et al., 2009).

In general, polarization from man-made electromagnetic radiation appears to have a greater bioactive effect than natural radiation, and significantly increases the probability for initiation of biological or health effects (Panagopoulos et al., 2015).

Tree damages as in Bamberg and Hallstadt were documented by the authors in several countries: Spain (Valladolid, Salamanca, Madrid, Palencia, León), Germany (Munich, Nürnberg, Erlangen, Bayreuth, Neuburg/Donau, Garmisch-Partenkirchen, Murnau, Stuttgart, Kassel, Fulda, Göttingen, biosphere reserve Rhön, Tegernsee Valley and in several small towns), Austria (Graz), Belgium (Brussels) and Luxemburg.

Each phone mast can harm many trees and each tree can be affected by several phone masts belonging to the same or different base stations. Damaged trees seem to exist around each antenna and the several million phone masts in the world could potentially be damaging the growth and health of millions of trees. This can occur not only in cities, but also in well-preserved forests, and in natural and national parks, where base stations are being installed without the necessary prior environmental impact studies, due to a lack of knowledge of the problem. For this reason, it is essential for an assessment on the environmental impact of any new base station prior to implementation.

Additionally, phone masts can cause a drop in timber productivity in plantations of pine, poplar, etc., as well as fruits, nuts, etc. Thus, the industry must be required to pay damages to plantation owners. Similarly, as trees are a common social good, the industry should compensate for damaged and dead trees around the world due to radiation. Further, the money spent by municipalities to repair or replace damaged trees should enter into the computation of costs/benefits of this technology. For installation of any new technology, the burden of proof should be to the industry that requires demonstration of safety prior to deployment.

Electromagnetic radiation from telecommunication antennas affected the abundance and composition of wild pollinators in natural habitats and these changes in the composition of pollinator communities associated with electromagnetic smog may have important ecological and economic impacts on the pollination service that could significantly affect the maintenance of wild plant diversity, crop production and human welfare (Lázaro et al., 2016).

Evidence for plant damage due to high frequency electromagnetic radiation was not taken into account in determining the current statutory regulations (the limit values). Once the problem becomes evident, the guidelines of radiation emitted by the antennas should be reviewed. Proper risk assessment of electromagnetic radiation should be undertaken to develop management strategies for reducing this pollution in the natural environment (Kumar et al., 2015).

Moreover, due to the lack of recognition, certain modern projects with interesting ideas for decreasing environmental pollution could have opposite effects than expected. For example, in the Netherlands, the TreeWiFi project (http://treewifi.org/), which aims to motivate people to use bikes and public transport in order to reduce the [NO2] pollution providing free WiFi when air quality improves, could be favoring electromagnetic pollution with even more harmful effects as it has been demonstrated in this manuscript (see also: http://www.greenpeace.org/canada/fr/Blog/le-wi-fi-tuerait-les-ar-bres/blog/33569/).

In addition, the number of sector antennas has increased in Bamberg and this increase appears to be accelerating: 483 sector antennas in 2011 and 779 sector antennas in 2015. Both radiation and damaged trees represent a loss of quality of life for citizens. This study began after finding that patients who claimed to be affected by phone masts, referred to as radiation, live in areas where affected trees and plants are located. Evidence of radiation damage was even found in potted plants inside patient homes (Waldmann-Selsam and Eger, 2013). Thus, this study is certainly complementary to the study by Eger and Jahn (2010) and other research that has shown effects on the health of people by phone masts located in their vicinity (Santini et al., 2002; Eger et al., 2004; Wolf and Wolf, 2004; Abdel-Rassoul et al., 2007; Khurana et al., 2010; Dode et al., 2011; Gómez-Perretta et al., 2013; Shahbazi-Gahrouei et al., 2014; Belyaev et al., 2015).

In the introduction to the International Seminar on “Effects of Electromagnetic Fields on the Living Environment” in 1999 in Ismaning, Germany, organized by WHO, ICNIRP and German Federal Office for Radiation Protection (BfS), M. Repacholi, head of the International EMF Project of the WHO, said: “By comparison, influences of these fields on plants, animals, birds and other living organisms have not been properly examined. Given that any adverse impacts on the environment will ultimately affect human life, it is difficult to understand why more work has not been done. There are many questions that need to be raised: …” and “…it seems that research should focus on the long-term, low-level EMF exposure for which almost no information is available. Specific topics that need to be addressed include: … EMF influences on agricultural plants and trees” (Matthes et al., 2000).

5. Conclusions

In this study we found a high-level damage in trees within the vicinity of phone masts. Preliminary laboratory studies have indicated some deleterious effects of radiofrequency radiation. However, these early warnings have had no success and deployment has been continued without consideration of environmental impact.

We observed trees with unilateral damage in the radiation field of phone masts. We excluded the possibility that root injury due to construction work or air pollutants could have caused the unilateral damage. We found out that from the damaged side there was always visual contact to one or more phone mast (s).

Statistical analyses demonstrated that the electromagnetic radiation from cellphone towers is harmful to trees. Results show that the measurements in the most affected sides of damaged trees (i.e. those that withstand higher radiation levels) are different to all other groups. These results are consistent with the fact that damage inflicted on

trees by cellphone towers usually start on one side, extending to the whole tree over time.

The occurrence of unilateral damage is the most important fact in our study and an important argument for a causal relationship with RF-EMF, as it supplies evidence for non-thermal RF-EMF effects. This constitutes a danger for trees worldwide. The further deployment of phone masts has to be stopped. Scientific research on trees under the real radiofrequency field conditions must continue.

Acknowledgements

The work presented here was carried out without any funding. Francisco Cabrero and José Ignacio Aguirre from the Department of Zoology, University Complutense of Madrid suggested the interpolation points on the map of radiation. This paper is dedicated in memoriam to the great Swedish researcher and courageous man, Örjan Hallberg. Authors have not a conflict of interest to declare.

References

Abdel-Rassoul, G., El-Fateh, O.A., Salem, M.A., Michael, A., Farahat, F., El-Batanouny, M., Salem, E., 2007. Neurobehavioral effects among inhabitants around mobile phone base stations. Neurotoxicology 28, 434–440.

Balmori, A., 2004. Pueden afectar las microondas pulsadas emitidas por las antenas de telefonía a los árboles y otros vegetales? Ecosistemas 13, 79–87.

Balmori, A., 2014. Electrosmog and species conservation. Sci. Total Environ. 496, 314–316.

Balmori, A., 2015. Anthropogenic radiofrequency electromagnetic fields as an emerging threat to wildlife orientation. Sci. Total Environ. 518, 58–60.

Balodis, V.G., Brumelis, K., Kalviskis, O., Nikodemus, D., Tjarve, V.Z., 1996. Does the Skrunda Radio Location Station disminish the radial growth of pine trees? Sci. Total Environ. 180, 57–64.

Beaubois, E., Girard, S., Lallechere, S., Davies, E., Paladian, F., Bonnet, P., Ledoit, G., Vian, A., 2007. Intercellular communication in plants: evidence for two rapidly transmitted systemic signals generated in response to electromagnetic field stimulation in tomato. Plant Cell Environ. 30, 834–844.

Belyaev, I., 2010. Dependence of non-thermal biological effects of microwaves on physical and biological variables: implications for reproducibility and safety standards. In: Giuliani, L., Soffritti, M. (Eds.), European Journal of Oncology - Library Non-thermal effects and mechanisms of interaction between electromagnetic fields and living matterAn ICEMS Monograph vol. 5. RAMAZZINI INSTITUTE, Bologna, Italy (http://www.icems.eu/papers.htm?f=/c/a/2009/12/15/MNHJ1B49KH.DTL).

Belyaev, I., Dean, A., Eger, H., Hubmann, G., Jandrisovits, R., Johansson, O., Moshammer, H., Kern, M., Kundi, M., Lercher, P., Mosgoller, W., Moshammer, H., Muller, K., Oberfeld, G., Ohnsorge, P., Pelzmann, P., Scheingraber, C., Thill, R., 2015. EUROPAEM EMF Guideline 2015 for the prevention, diagnosis and treatment of EMF-related health problems and illnesses. Rev. Environ. Health 30, 337–371.

Bernatzky, A., 1986. Elektromagnetischer Smog – Feind des Lebens. Der Naturarzt 11, 22–25 (http://www.diewellenbrecher.de/pdf/bernatzky.pdf).

Brauer, I., 1950. Experimentelle Untersuchungen über die Wirkung von Meterwellen verschiedener Feldstärke auf das Teilungswachstum der Pflanzen. Chromosoma 3, 483–509 (http://www.springerlink.com/content/kqn177g8g5114787/, letzter Zugriff: 30.5.2013).

Cammaerts, M.C., Johansson, O., 2015. Effect of man-made electromagnetic fields on common Brassicaceae *Lepidium sativum* (cress d'Alinois) seed germination: a preliminary replication study. Fyton 84, 132–137.

Dode, A.C., Leão, M.M., de AF Tejo, F., Gomes, A.C., Dode, D.C., Dode, M.C., Caiaffa, W.T., 2011. Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil. Sci. Total Environ. 409, 3649–3665.

Eger, H., Uwe, K., Hagen, B., Lucas, P., Vogel, P., Voit, H., 2004. Einfluss der räumlichen Nähe von Mobilfunksendeanlagen auf die Krebsinzidenz. Umwelt Med. Ges. 17, 326–332.

Eger, H., Jahn, M., 2010. Specific symptoms and radiation from mobile basis stations in Selbitz, Bavaria, Germany: evidence for a dose-effect relationship (original article in German). Umwelt Med. Ges. 23, 130–139.

ESRI (Environmental Systems Research Institute), 2008. ArcMap 9.3 (Build 1770). ESRI® ArcGIS, 9, 1999–2008.

Gómez-Perretta, C., Navarro, E.A., Segura, J., Portolés, M., 2013. Subjective symptoms related to GSM radiation from mobile phone base stations: a cross-sectional study. BMJ open 3 (12), e003836.

Grémiaux, A., Girard, S., Guérin, V., Lothier, J., Baluška, F., Davies, E., Bonnet, P., Vian, A., 2016. Low-amplitude, high-frequency electromagnetic field exposure causes delayed and reduced growth in Rosa hybrid. J. Plant Physiol. 190, 44–53.

Haggerty, K., 2010. Adverse influence of radio frequency background on trembling aspen seedlings: preliminary observations. Int. J. For. Res. 2010, 836278.

Halgamuge, M.N., Yak, S.K., Eberhardt, J.L., 2015. Reduced growth of soybean seedlings after exposure to weak microwave radiation from GSM 900 mobile phone and base station. Bioelectromagnetics 36, 87–95.

Harte, C., 1950. Mutationsauslösung durch Ultrakurzwellen. Chromosoma 3, 140–147.

Harte, C., 1972. Auslösung von Chromosomenmutationen durch Meterwellen in Pollenmutterzellen von Oenothera. Chromosoma 36, 329–337 (http://www.springerlink.com/content/x32049jrnm4u7858/).

Hussein, R.A., El-Maghraby, M.A., 2014. Effect of two brands of cell phone on germination rate and seedling of wheat (*Triticum aestivum*). J. Environ. Pollut. Human Health 2, 85–90.

IARC, 2013. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Non-ionizing Radiation, Part 2: Radiofrequency Electromagnetic Fields vol. 102. IARC Press, Lyon, France (http://monographs.iarc.fr/ENG/Monographs/vol102/mono102.pdf).

I. C. N. I. R. P., 1998. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Phys. 74 (4), 494–522.

Jayasanka, S.M.D.H., Asaeda, T., 2013. The significance of microwaves in the environment and its effect on plants. Environ. Rev. 22, 220–228.

Jerman, I., Berden, M., Ruzic, R., Skarja, M., 1998. Biological effects of TV set electromagnetic fields on the growth of spruce seedlings. Electromagn. Biol. Med. 17, 31–42.

Kiepenheuer, K.O., Brauer, I., Harte, C., 1949. Über die Wirkung von Meterwellen auf das Teilungswachstum der Pflanzen. Naturwissenschaften 36, 27.

Kundu, A., IEEE, 2013. Specific Absorption Rate evaluation in apple exposed to RF radiation from GSM mobile towers. IEEE Applied Electromagnetics Conference (AEMC). IEEE, pp. 1–2 (ISBN 978-1-4799-3266-5).

Khurana, V.G., Hardell, L., Everaert, J., Bortkiewicz, A., Carlberg, M., Ahonen, M., 2010. Epidemiological evidence for a health risk from mobile phone base stations. Int. J. Occup. Environ. Health 16, 263–267.

Kumar, A., Singh, H.P., Batish, D.R., Kaur, S., Kohli, R.K., 2015. EMF radiations (1800 MHz)-inhibited early seedling growth of maize (*Zea mays*) involves alterations in starch and sucrose metabolism. Protoplasma 1–7.

Lázaro, A., Chroni, A., Tscheulin, T., Devalez, J., Matsoukas, C., Petanidou, T., 2016. Electromagnetic radiation of mobile telecommunication antennas affects the abundance and composition of wild pollinators. J. Insect Conserv. 1–10 http://dx.doi.org/10.1007/s10841-016-9868-8.

Lerchl, D., Lerchl, A., Hantsch, P., et al., 2000. Studies on the effects of radio-frequency fields on conifers, Kurzmitteilung auf der Tagung der Bioelectromagnetics Society in München. http://www.boomaantastingen.nl/EMF_and_conifers%5B1%5D.pdf.

Matthes, R., Bernhardt, J.H., Repacholi, M.H., 2000. Effects of electromagnetic fields on the living environment. Proceedings International Seminar on Effects of Electromagnetic Fields on the Living Environment – Ismaning, Germany, October 4 and 5, 1999, ICNIRP 10/2000.

Meng, Y.S., Lee, Y.H., 2010. Investigations of foliage effect on modern wireless communication systems: a review. Prog. Electromagn. Res. 105, 313–332.

Pall, M., 2016. Electromagnetic fields act similarly in plants as in animals: probable activation of calcium channels via their voltage sensor. Curr. Chem. Biol. (http://benthamscience.com/journals/current-chemical-biology/article/141390/).

Panagopoulos, D.J., Johansson, O., Carlo, G.L., 2015. Polarization: a key difference between man-made and natural electromagnetic fields, in regard to biological activity. Sci. Rep. 5, 14914. http://dx.doi.org/10.1038/srep14914.

Panagopoulos, D.J., Cammaerts, M.C., Favre, D., Balmori, A., 2016. Comments on environmental impact of radiofrequency fields from mobile phone base stations. Crit. Rev. Environ. Sci. Technol. http://dx.doi.org/10.1080/10643389.2016.1182107.

Pesnya, D.S., Romanovsky, A.V., 2013. Comparison of cytotoxic and genotoxic effects of plutonium-239 alpha particles and mobile phone GSM 900 radiation in the *Allium cepa* test. Mutat. Res. Genet. Toxicol. Environ. Mutagen. 750, 27–33.

QGIS Development Team, 2014. Quantum GIS geographic information system version 2.6.0-Brighton [Internet]. http://qgis.osgeo.org.

Roux, D., Vian, A., Girard, S., Bonnet, P., Paladian, F., Davies, E., Ledoigt, G., 2006. Electromagnetic fields (900 MHz) evoke consistent molecular responses in tomato plants. Physiol. Plant. 128, 283–288.

Roux, D., Vian, A., Girard, S., Bonnet, P., Paladian, F., Davies, E., Ledoigt, G., 2008. High frequency (900 MHz) low amplitude (5 V m — 1) electromagnetic field: a genuine environmental stimulus that affects transcription, translation, calcium and energy charge in tomato. Planta 227, 883–891.

Sandu, D.D., Goiceanu, C., Ispas, A., Creanga, I., Miclaus, S., Creanga, D.E., 2005. A preliminary study on ultra high frequency electromagnetic fields effect on black locust chlorophylls. Acta Biol. Hung. 56, 109–117.

Santini, R., Santini, P., Danze, J.M., Le Ruz, P., Seigne, M., 2002. Study of the health of people living in the vicinity of mobile phone base stations: I. Influences of distance and sex. Pathol. Biol. 50, 369–373.

Schmutz, P., Siegenthaler, J., Stäger, C., Tarjan, D., Bucher, J.B., 1996. Long-term exposure of young spruce and beech trees to 2450 MHz microwave radiation. Sci. Total Environ. 180, 43–48.

Schorpp, V., 2011. Tree damage from chronic high frequency exposure. The effect of electromagnetic radiation on trees, First symposium February 18, 2011, Lecture, Baan, Netherlands (http://www.puls-schlag.org/download/Schorpp-2011-02-18.pdf).

Selga, T., Selga, M., 1996. Response of *Pinus sylvestris* L. needles to electromagnetic fields. Cytological and ultrastructural aspects. Sci. Total Environ. 180, 65–73.

Shahbazi-Gahrouei, D., Karbalae, M., Moradi, H.A., Baradaran-Ghahfarokhi, M., 2014. Health effects of living near mobile phone base transceiver station (BTS) antennae: a report from Isfahan, Iran. Electromagn. Biol. Med. 33, 206–210.

Sharma, V.P., Singh, H.P., Kohli, R.K., Batish, D.R., 2009. Mobile phone radiation inhibits *Vigna radiata* (mung bean) root growth by inducing oxidative stress. Sci. Total Environ. 407, 5543–5547.

StatSoft, Inc, 2004. STATISTICA (data analysis software system), version 7. www.statsoft.com.

Stefi, A.L., Margaritis, L.H., Christodoulakis, N.S., 2016. The effect of the non ionizing radiation on cultivated plants of *Arabidopsis thaliana* (Col.). Flora 223, 114–120.

Tkalec, M., Malarić, K., Pevalek-Kozlina, B., 2005. Influence of 400, 900, and 1900 MHz. electromagnetic fields on *Lemna minor* growth and peroxidase activity. Bioelectromagnetics 26, 185–193.

Tkalec, M., Malarić, K., Pavlica, M., Pevalek-Kozlina, B., Vidaković-Cifrek, Ž., 2009. Effects of radiofrequency electromagnetic fields on seed germination and root meristematic cells of *Allium cepa* L. Mutat. Res. Genet. Toxicol. Environ. Mutagen. 672, 76–81.

Van't Wout, N., 2006. Unkown tree damage. http://www.boomaantastingen.nl.

Vian, A., Davies, E., Gendraud, M., Bonnet, P., 2016. Plant responses to high frequency electromagnetic fields. Biomed. Res. Int. 2016, 1830262. http://dx.doi.org/10.1155/2016/1830262.

Volkrodt, W., 1987. Wer ist am Waldsterben schuld? Mikrowellensmog der Funk- und Nachrichtensysteme. Raum Zeit 26, 53–62.

Volkrodt, W., 1991. Droht den Mikrowellen ein ähnliches Fiasko wie der Atomenergie? Wetter-Boden-Mensch 4, 16–23.

Waldmann-selsam, C., 2007. Mikrowellensyndrom – ein neues Krankheitsbild, Vortrag, 6. Rheinland-Pfälzisch-Hessisches Mobilfunksymposium, 14.4.2007, BUND Rheinland-Pfalz, Mainz. http://www.bund-rlp.de/publikationen/tagungsbaende/mobilfunksymposium/6_mobilfunksymposium/.

Waldmann-Selsam, C., Eger, H., 2013. Baumschäden im Umkreis von Mobilfunksendeanlagen. Umwelt Med. Ges. 26, 198–208 (http://kompetenzinitiative.net/KIT/wp-content/uploads/2016/06/Tree-damages-in-the-vicinity-of-mobile-phone-base-stations.pdf).

Wolf, R., Wolf, D., 2004. Increased incidence of cancer near a cell-phone transmitter station. Int. J. Cancer 1, 123–128.

Biosystem & Ecosystem; The Dangers of Electromagnetic Smog,
Prof. Andrew Goldsworthy, PhD.; 2007

The Dangers of Electromagnetic Smog

Andrew Goldsworthy, August 2007

Weak non-ionising electromagnetic radiation in the environment can be linked to more 'modern illnesses' than even the pessimists thought possible. Modern science can now begin to explain how.

Abstract

Weak electromagnetic radiation removes structurally important calcium (and possibly magnesium) ions from cell membranes, making them weaker and more prone to transient pore formation. This makes them leaky to even large molecules. Prolonged exposure to mobile phone radiation causes serious damage to the DNA in living cells, probably because of digestive enzymes leaking from lysosomes. This may be responsible for the reduction in sperm quantity and quality found in recent studies of people using mobile phones for more than a few hours a day. We might also expect it lead to an increase in the incidence of cancer, but this may not become apparent for many years. Electromagnetic exposure also increases the permeability of the blood-brain barrier to large molecules and allows potentially damaging substances to enter the brain from the bloodstream. The blood-brain barrier is characterised by having cells joined by 'tight junctions', where the gaps between the cells are sealed by impermeable materials. Equivalent layers of cells with tight junctions cover all of our body surfaces and a similar increase in their permeability could allow the entry of a wide range of potential toxins, allergens and carcinogens from the environment. There is evidence that this increase in permeability is mediated by the loss of calcium from cell membranes and should also be enhanced by electromagnetic exposure. This effect can link the current rise in the incidence of multiple chemical sensitivities, various allergy-related diseases and skin cancer to the electromagnetic environment. Electrosensitive individuals can be thought of as people who have abnormally weak permeability barriers that are more easily compromised by electromagnetically-induced calcium or magnesium loss. In general, the symptoms resemble those of hypocalcaemia and hypomagnesaemia, which suggests a common aetiology based on a reduction in membrane stability. Low concentrations of either calcium or magnesium ions in the blood may be predisposing factors, but once the condition is established, it can be progressive with increasing exposure to radiation. It then appears to be irreversible.

Introduction

Nearly all of us are exposed to weak non-ionising electromagnetic radiation from all sorts of electrical appliances and even the wiring in our own homes. If we could see it, it would look like a fog over almost everything, with particularly dense patches around people using mobile phones and DECT cordless phones. There would be other dense patches hovering permanently over their base stations and Wi-Fi routers. People have dubbed this

'electromagnetic smog' and, like real smog, it can have serious effects on our health. Electrosensitive people have known this for a long time because they experience pain and other symptoms when they are exposed to the denser patches. However, the dangers go well beyond that. Many people have attributed the recent rise in the incidence of a large number of medical conditions such as asthma, other allergies, various cancers, diabetes and multiple sclerosis to electromagnetic exposure. However, until very recently no one has been able explain just how this could happen, but we are now learning about the likely mechanisms and just how serious the situation is.

Calcium loss makes cell membranes porous

The most important factor giving adverse health effects from electromagnetic exposure seems to be the electromagnetically-induced loss of calcium ions (electrically charged calcium atoms) from cell membranes. We have known for over thirty years that weak electromagnetic fields remove calcium ions from the surfaces of cell membranes (Bawin et al. 1975.; Blackman et al. 1982; Blackman 1990). In theory, magnesium ions can be removed by a similar mechanism (See Goldsworthy 2006). However, divalent ions (ions with a double charge) such as calcium are important in maintaining membrane stability (Steck et al. 1970; Lew et al. 1988; Ha 2001) and their loss would make the membranes more prone to the formation of transient pores and increase their general permeability to a wide range of materials.

Pore formation can have many biological effects

Spontaneous pore formation has already been reported in stationary artificial phospholipid membranes exposed to DC fields (Melikov et al. 2001) and we would expect an even greater effect on the membranes of living cells, which are routinely subjected to stresses and strains from being adjacent to moving cytoplasm. If these membranes were in addition suffering from electromagnetically-induced calcium depletion, we would expect pore formation to be more frequent and give rise to larger pores that are slower to heal. In this way, exposure to weak non-ionising radiation would give a non-specific increase in membrane permeability. Such an increase can explain a large number of non-thermal biological effects of electromagnetic fields, ranging from changes in the growth rate of plants to accelerated rates of healing and changes in gene expression in animals (See Goldsworthy 2006; 2007). However, it can also cause serious damage.

Mobile phone radiation can damage DNA

Low-level, non-thermal (i.e. not strong enough to generate significant heat) microwave radiation similar to that from mobile phones has been shown to do serious damage to the DNA in cultures of living cells. Lai and Singh (1995) were the first to show this in rat brain cells, but many other workers have since confirmed it. The most comprehensive study on this was the Reflex Project sponsored by the European Commission and replicated in laboratories in several European countries. They found that radiation from GSM mobile phone handsets caused both single and double stranded breaks in the DNA of cultured human and animal cells. Not all cell types were equally affected and some seemed not to be affected at all (Reflex Report 2004). The degree of damage depended on the duration of

the exposure. With human fibroblasts, it reached a maximum at around 16 hours. Intermittent exposure (5 minutes on, ten minutes off) was considerably more damaging than continuous exposure, thus emphasising its non-thermal nature. (Diem et al. 2005). Because of the high stability of DNA molecules, the only plausible mechanism for this so far is the release of DNAase and possibly other digestive through the membranes of lysosomes (organelles that digest waste) that had been perforated or ruptured by the radiation. If this is correct, there is likely to be considerable collateral damage to other cellular systems.

If similar DNA fragmentation were to occur in the whole organism, we would expect a more or less immediate reduction in male fertility as developing sperm become damaged, an increased risk of cancer, which (by analogy with tobacco and asbestos) may take several years to appear, and genetic mutations that will appear in future generations. It would be unwise to assume that exposures of less than 16 hours are necessarily safe, since covert DNA damage to give aberrant cells could occur long before it becomes obvious under the microscope. Claims made by the mobile phone industry that their devices are safe because not all cells are affected are rather like clutching at straws, since very few genetically aberrant cells are needed to initiate a tumour.

Mobile phones can reduce fertility

We might expect DNA damage to result in a loss of fertility. Recent studies have shown significant reductions in sperm motility, viability and quantity in men using mobile phones for more than a few hours a day (Fejes et al. 2005; Agarwal et al. 2006; Agarwal et al. 2007) so it is advisable to keep your mobile calls to a minimum. Since similar experiments have not yet been performed with mobile phone base stations, it would be premature to assume that they are necessarily safe, particularly since living near one will involve a considerably longer exposure.

Electromagnetic exposure disrupts tight junction barriers

We might expect radiation that is strong enough to disrupt lysosomes also to be strong enough to disrupt the outer membranes of cells so that these too are made more permeable to large molecules. The effects of this would be most serious in the cells of the various barriers within our bodies that prevent the passage of unwanted substances. These are characterised by cells joined by 'tight junctions', in which the gaps between the cells are sealed with impermeable materials to prevent leakage around their sides. One such barrier is the blood-brain barrier, which normally prevents unwanted substances in the bloodstream from entering the brain. We know that the radiation from mobile phones can increase the permeability of this barrier even to protein molecules as large as albumin (Persson et al. 1997) and this increase in permeability can damage the neurones beneath (Salford et al. 2003).

Calcium ions control barrier tightness

The loss in tightness of the blood-brain barrier could be due to an increase in membrane leakiness as proposed by Goldsworthy (2006; 2007) and/or to a disruption of the tight

junctions themselves, either of which could be triggered by an electromagnetically-induced loss of calcium from their membranes. The central role of membrane-bound calcium in controlling the 'tightness' of these layers is supported by an observation by Chu et al. (2001). They found that either low levels of external calcium or the addition of EGTA (a substance that removes calcium ions from surfaces) caused massive increases in the electrical conductance and permeability to virus particles of respiratory epithelia, which also has tight junctions.

We have many other tight junction barriers

There is a protective layer in the skin in the *stratum granulosum*, which is the outermost layer of living skin cells, in which the cells are connected by tight junctions (Borgens et al. 1989; Furuse et al. 2002). In addition to this, virtually all of our other body surfaces are protected by cells with tight junctions, including the nasal mucosa (Hussar et al. 2002), the lungs (Weiss et al. 2003) and the lining of the gut (Arrieta et al. 2006). A similar electromagnetically-induced increase in the permeability of any of these would allow the more rapid entry into the body of a whole range of foreign materials, including allergens, toxins and carcinogens.

Loss of tightness can exacerbate many illnesses

Electromagnetically induced losses of barrier tightness at our body surfaces can explain how the general increase in public exposure to electromagnetic fields may be responsible for our ever-increasing susceptibility to various allergies, multiple chemical sensitivities, asthma, skin rashes and bowel cancer to name just a few. In addition, a non-specific increase in the permeability of the gut has been linked to type-1 diabetes, Crohns disease, celiac disease, multiple sclerosis, irritable bowel syndrome and a range of others (Arrieta et al. 2006). The list is truly horrendous and points to a very real need to reduce our exposure to non-ionising radiation.

Electrosensitivity

Electrosensitivity (sometimes called electromagnetic hypersensitivity) is a condition in which some people experience a wide range of unpleasant symptoms when exposed to weak non-ionising radiation. Only a small proportion of the population is electrosensitive (currently estimated at around three percent) and an even smaller proportion is so badly affected that they can instantly tell whether a device is switched on or off. At the other end of the scale, there are people who may be electrosensitive but do not know it because they are chronically exposed to electromagnetic fields and accept their symptoms (headaches, pins and needles, numbness, fatigue, irritability and many others.) as being perfectly normal. Electrosensitivity is in effect a continuum and there is no clear cut-off point.

Causes and symptoms of electrosensitivity

The cause of the condition is uncertain and not everyone shows the same symptoms, but they seem to be characterised by having skins that have an unusually high electrical

conductance (Eltiti *et al.* 2007). This is consistent with them having a *stratum granulosum* which is abnormally leaky, and may account for the high incidence of allergies and chemical sensitivities commonly found in this group. One explanation for this is that they normally have asymptomatic low levels of calcium and/or magnesium in their blood, which gives low concentrations of these ions on their cell membranes. This means that less has to be removed by electromagnetic exposure to produce biological effects; hence their greater sensitivity.

The range of electromagnetically-induced symptoms reported by electrosensitives, which includes skin disorders, various paresthesias (pins and needles, numbness, burning sensations) fatigue, muscle cramps, cardiac arrhythmia, and gastro-intestinal problems are remarkably similar to those from hypocalcaemia (low blood calcium) (http://tinyurl.com/2dwwps) and hypomagnesaemia (low blood magnesium) (http://tinyurl.com/3ceevs). This suggests that they share a common aetiology, that being that there are inadequate concentrations of these divalent ions on the cell membranes to maintain stability, which promotes poration and gives rise to an unregulated flow of materials across them. If a patient reporting symptoms of electrosensitivity is diagnosed as having sub-clinical low levels of either of these ions in the blood, and if caught at an early stage, it may be possible to mitigate the effects of electromagnetic exposure by conventional treatment for hypocalcaemia and/or hypomagnesaemia.

Unfortunately, it does not end there. When electrosensitive people to are subjected to further exposure to electromagnetic fields, it seems to do permanent damage. This could be due to DNA or other cellular damage from ruptured lysosomes. The affected cells may then not function properly and become incapable of protecting themselves fully from further damage. This could include an ever-increasing loss of their ability to form adequate tight junction barriers, so making the victim progressively more sensitive to the radiation. It is important, therefore, to protect electrosensitive people from further electromagnetic exposure, but sadly, there is no Government provision for this in the UK because the condition is not officially recognised.

Postscript

Virtually all of the observations cited above came originally from peer-reviewed journals. I obtained them in my retirement by piecing together the findings from many scientific papers, often on unrelated topics, for which I thank the Library at Imperial College. However, there has been very little research specifically directed at discovering, either the full range of the adverse health effects of electromagnetic exposure or of the mechanisms by which they occur. I hope that the time for this will soon come. In the meantime, if you would like to learn more about electromagnetic fields and how to avoid them, visit www.powerwatch.org.uk. If you want to know more about electrosensitivity, visit www.es-uk.info.

References

Agarwal A, Prabakaran SA, Ranga G, Sundaram AT, Shama RK, Sikka SC (2006), 'Relationship between cell phone use and human fertility: an observational study'.

Fertility and Sterility 86 (3) Supplement 1 S283. Data also available at http://tinyurl.com/28rm6n

Agarwal A, Deepinder F, Rakesh K, Sharma RK, Ranga G, Li J (2007), 'Effect of cell phone usage on semen analysis in men attending infertility clinic: an observational study'. *Fertility and Sterility*. In press (available online - doi:10.1016/j.fertnstert.2007.01.166)

Arrieta MC, Bistritz L, Meddings JB (2006), 'Alterations in intestinal permeability'. *Gut* 55: 1512-1520

Bawin SM, Kaczmarek KL, Adey WR (1975), 'Effects of modulated VHF fields on the central nervous system'. *Ann NY Acad Sci* 247: 74-81

Blackman CF (1990), 'ELF effects on calcium homeostasis'. In: Wilson BW, Stevens RG, Anderson LE (eds) *Extremely Low Frequency Electromagnetic Fields: the Question of Cancer*. Battelle Press, Columbus, Ohio, pp 189-208

Blackman CF, Benane SG, Kinney LS, House DE, Joines WT (1982), 'Effects of ELF fields on calcium-ion efflux from brain tissue in vitro'. *Radiation Research* 92: 510-520

Borgens RB, Robinson, KR, Vanable JW, McGinnis ME (1989), *Electric Fields in Vertebrate Repair*. Liss, New York

Chu Q, George ST, Lukason M, Cheng SH, Scheule RK, Eastman SJ (2001), 'EGTA enhancement of adenovirus-mediated gene transfer to mouse tracheal epithelium in vivo'. *Human Gene Therapy* 12: 455-467

Diem E, Schwarz C, Adlkofer F, Jahn O, Rudiger H (2005), 'Non-thermal DNA breakage by mobile phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro'. *Mutation Research / Genetic Toxicology and Environmental Mutagenesis* 583: 178-183

Eltiti S, Wallace D, Ridgewell A, Zougkou K, Russo R, Sepulveda F, Mirshekar-Syahkal D, Rasor P, Deeble R, Fox E (2007), 'Does short-term exposure to mobile phone base station signals increase symptoms in individuals who report sensitivity to electromagnetic fields? A double blind provocation study'. *Environmental Health Perspectives* http://www.ehponline.org/members/2007/10286/10286.pdf

Fejes I, Zavaczki Z, Szollosi J, Koloszar S, Daru J, Kovaks L, Pal A (2005), 'Is there a relationship between cell phone use and semen quality?' *Arch Andrology* 51: 385-393

Furuse M, Hata M, Furuse K, Yoshida Y, Haratake A, Sugitani Y, Noda T, Kubo A, Tsukita S (2002), 'Claudin-based tight junctions are crucial for the mammalian epidermal barrier: a lesson from claudin-1- deficient mice'. *J Cell Biol* 156; 1099-1111

Goldsworthy A (2006), 'Effects of electrical and electromagnetic fields on plants and related topics'. In: Volkov AG (ed) *Plant Electrophysiology – Theory and Methods*. Springer-Verlag, Berlin

Goldsworthy A (2007), 'The biological effects of weak electromagnetic fields'. http://tinyurl.com/2nfujj

Ha B-Y (2001), 'Stabilization and destabilization of cell membranes by multivalent ions'. *Phys Rev E* 64: 051902 (5 pages)

Hussar P, Tserentsoodol N, Koyama H, Yokoo-Sugawara M, Matsuzaki T, Takami S, Takata K (2002), 'The glucose transporter GLUT1 and the tight junction protein occludin in nasal olfactory mucosa'. *Chem Senses* 27: 2-11

Lew VL, Hockaday A, Freeman CJ, Bookchin RM (1988), 'Mechanism of spontaneous inside-out vesiculation of red cell membranes'. *J Cell Biol* 106: 1893-1901

Lai H, Singh NP (1995), Acute low-intensity microwave exposure increases DNA single-strand breaks in rat brain cells. Bioelectromagnetics 16: 207-210

Melikov KC, Frolov VA, Shcherbakov A, Samsonov AV, Chizmadzhev YA, Chernomordik LV (2001), 'Voltage-induced nonconductive pre-pores and metastable single pores in unmodified planar lipid bilayer'. *Biophys J* 80: 1829-1836

Persson BRR, Salford LG, Brun A (1997), 'Blood-brain barrier permeability in rats exposed to electromagnetic fields used in wireless communication'. *Wireless Networks* 3: 455–461

Reflex Report (2004), http://www.powerwatch.org.uk/reports/20041222_reflex.pdf

Salford LG, Brun AE, Eberhardt JL, Malmgren K, Persson BRR (2003), 'Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones'. *Environmental Health Perspectives* 111: 881-883

Steck TL, Weinstein RS, Straus, JH, Wallach DFH (1970), 'Inside-out red cell membrane vesicles: preparation and purification'. *Science* 168: 255-257

Weiss DJ, Beckett T, Bonneau L, Young J, Kolls JK, Wang G (2003), 'Transient increase in lung epithelial tight junction permeability: an additional mechanism for of enhancement of lung transgene expression by perfluorochemical liquids'. *Molecular Therapy* 8: 927-935

Andrew Goldsworthy BSc PhD is an Honorary Lecturer in Biology at Imperial College London

Biosystem & Ecosystem; Impacts of radio-frequency electromagnetic field (RF-EMF) from cell phone towers and wireless devices on biosystem and ecosystem – a review. Biology and Medicine. (S. Sivani et al); 2012

eISSN: 09748369

Impacts of radio-frequency electromagnetic field (RF-EMF) from cell phone towers and wireless devices on biosystem and ecosystem – a review

Biology and Medicine

Review Article

Volume 4, Issue 4, Pages 202–216, 2012

Review Article *Biology and Medicine, 4 (4): 202–216, 2012*

www.biolmedonline.com

Impacts of radio-frequency electromagnetic field (RF-EMF) from cell phone towers and wireless devices on biosystem and ecosystem – a review

S Sivani*, D Sudarsanam
Department of Advanced Zoology and Biotechnology, Loyola College, Chennai, Tamil Nadu, India.

***Corresponding Author:** sivani.padmakumar@gmail.com

Accepted: 3rd Dec 2012, Published: 6th Jan 2013

Abstract
This paper summarizes the effect of radio-frequency electromagnetic field (RF-EMF) from cell towers and wireless devices on the biosphere. Based on current available literature, it is justified to conclude that RF-EMF radiation exposure can change neurotransmitter functions, blood-brain barrier, morphology, electrophysiology, cellular metabolism, calcium efflux, and gene and protein expression in certain types of cells even at lower intensities. The biological consequences of such changes remain unclear. Short-term studies on the impacts of RF-EMF on frogs, honey bees, house sparrows, bats, and even humans are scarce and long-term studies are non-existent in India. Identification of the frequency, intensity, and duration of non-ionizing electromagnetic fields causing damage to the biosystem and ecosystem would evolve strategies for mitigation and would enable the proper use of wireless technologies to enjoy its immense benefits, while ensuring one's health and that of the environment.

Keywords: Radio-frequency electromagnetic field; cell phone tower; power density; SAR; non-ionizing radiation; non-thermal.

Introduction

There has been an unprecedented growth in the global communication industry in recent years which has resulted in a dramatic increase in the number of wireless devices. Mobile services were launched in India in 1995 and it is one of the fastest growing mobile telephony industries in the world. According to the Telecom Regulatory Authority of India (TRAI, 2012), the composition of telephone subscribers using wireless form of communication in urban area is 63.27% and rural area is 33.20%. By 2013, it is estimated that more than one billion people will be having cell phone connection in India. This has led to the mushrooming of supporting infrastructure in the form of cell towers which provide the link to and from the mobile phone. With no regulation on the placement of cell towers, they are being placed haphazardly closer to schools, creches, public playgrounds, on commercial buildings, hospitals, college campuses, and terraces of densely populated urban residential areas. Hence, the public is being exposed to continuous, low intensity radiations from these towers. Since the electromagnetic radiations, also known as electrosmog cannot be seen, smelt or felt, one would not realize their potential harm over long periods of exposure until they manifest in the form of biological disorders. Various studies have shown the ill-effects of radio-frequency electromagnetic field (RF-EMF) on bees, fruit flies, frogs, birds, bats, and humans, but the long-term studies of such exposures are inconclusive and scarce, and almost non-existent in India (MOEF, 2010; DoT, 2010). In 2011, International Agency for Research on Cancer (IARC), part of WHO, designated RF-EMF from cell phones as a "possible human carcinogen" Class 2B (WHO, 2011). Cancer, diabetes, asthma, infectious diseases, infertility, neurodegenerative disorders, and even suicides are on the rise in India. This invisible health hazard pollution (IHHP) is a relatively new environmental threat.

Electromagnetic radiation, in the form of waves of electric and magnetic energy, have been circulating together through space. The electromagnetic spectrum includes radio waves, microwaves, infrared rays, light rays, ultraviolet rays, X-rays, and gamma rays (ARPANSA, 2011;

FCC, 1999). The electromagnetic radiations are of two types, one being ionizing radiations such as X-rays and gamma rays, and the other being non-ionizing radiations such as electric and magnetic fields, radio waves, radio-frequency band which includes microwaves, infrared, ultraviolet, and visible radiation (Figure 1). The biological effects of RF-EMF at molecular level induce thermal and non-thermal damage, which may be due to dielectric heating leading to protein denaturation, polar molecular agitation, cellular response through molecular cascades and heat shock proteins, and changes in enzyme kinetics in cells (Instituto Edumed, 2010). The three major physical parameters of RF-EMF radiations is frequency, intensity, and exposure duration. Although the non-ionizing radiations are considered less dangerous than ionizing radiation, over-exposure can cause health hazards (FCC, 1999).

Electromagnetic Spectrum and RF-EMF Radiation

The RF-EMF radiations fall in the range of 10 MHz–300 GHz. Cell phone technology uses frequencies mainly between 800 MHz and 3 GHz and cell tower antenna uses a frequency of 900 or 1800 MHz, pulsed at low frequencies, generally known as microwaves (300 MHz–300 GHz).

Power Density and Specific Absorption Rate (SAR)

Variables used in the measurement of these radiations are power density, measured in watts per meter squared (W/m^2) and specific absorption rate (SAR). The term used to describe the absorption of RF-EMF radiation in the body is SAR, which is the rate of energy that is actually absorbed by a unit of tissue, expressed in watts per kilogram (W/kg) of tissue. The SAR measurements are averaged either over the whole body or over a small volume of tissue, typically between 1 and 10 g of tissue. SAR was set with the help of a phantom, known as specific anthropomorphic mannequin (SAM) derived from the size and dimensions of the 90th percentile large adult male reported in a 1988 US Army study who is 6 feet 2 inches and weighed 200 pounds (Davis, 2010). SAR is set at 1.6 W/kg averaged over 1 g of body tissue in the US and Canada and 2 W/kg averaged over 10 g of body tissue in countries adopting the ICNIRP guidelines. The SAR is used to quantify energy absorption to fields typically between 100 kHz and 10 GHz and encompasses radio-frequency radiation from devices such as cellular phones up through diagnostic magnetic resonance imaging (MRI). The biological effects depend on how much of the energy

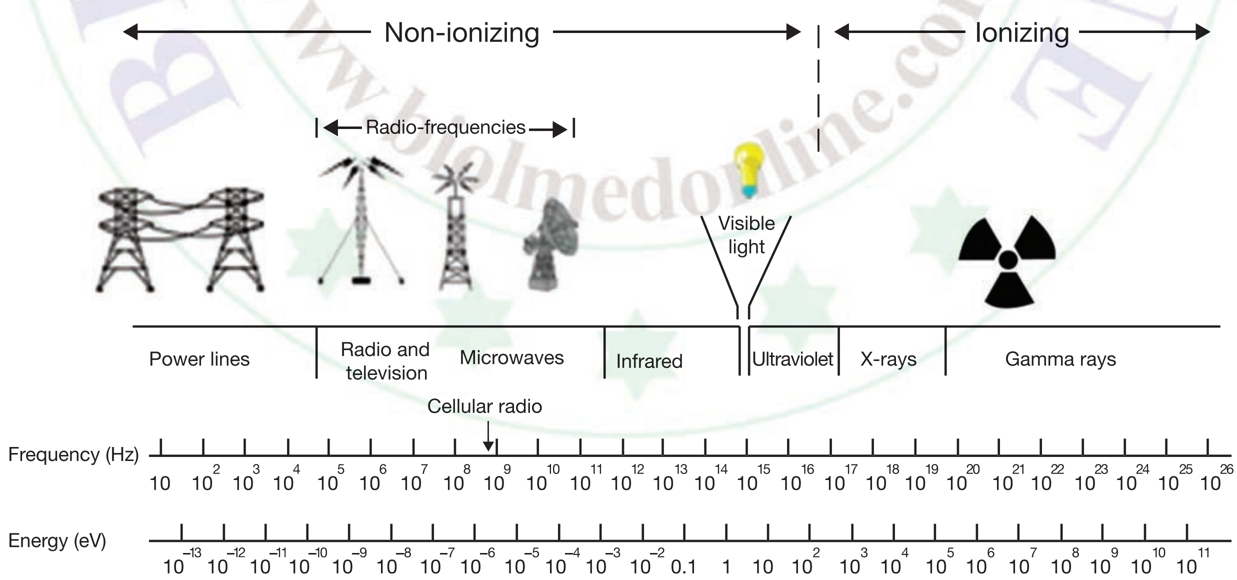


Figure 1: Electromagnetic spectrum from the Federal Communications Commission (FCC), OET Bulletin 56, 1999.

is absorbed in the body of a living organism, not just what exists in space. Absorption of RF-EMF radiations depend on frequency of transmission, power density, distance from the radiating source and the organism's size, shape, mineral, and water content. Exposure will be lower from towers under most circumstances than from cell phones because the transmitter is placed directly against the head during cell phone use whereas proximity to a cell tower will be an ambient exposure at a distance (Levitt and Lai, 2010). Exposure guidelines for RF protection had adopted the value of 4 W/kg averaged over the whole body (SARWB) as the threshold for the induction of adverse thermal effects associated with an increase of the body core temperature of about 1°C in animal experiments. This standard is set by International Commission on Non-ionizing Radiation Protection (ICNIRP), national Radiological Protection Board (NRPB), and Institute of Electrical and Electronics Engineers (IEEE) (Barnes and Greenebaum, 2007).

Cell Phones and Cell Tower Standards in India

India has adopted ICNIRP guidelines as the standard for safety limits of exposure to radio-frequency energy produced by mobile handsets for general public as follows: whole-body average SAR of 0.08 W/kg, localized SAR for head and trunk of 2 W/kg, and localized SAR for limbs 4 W/kg. The basic restrictions/proper limits for power density specified in ICNIRP guidelines for safe frequencies between 400 and 2000 MHz, adopted in India, for occupational exposure is 22.5 W/m^2, and general public is 4.5 W/m^2 for 900 MHz (ICNIRP, 1998).

Antennas of cell tower transmit in the frequency range of 869–890 MHz for CDMA, 935–960 MHz for GSM-900, 1805–1880 MHz for GSM-1800, and 2110–2170 MHz for 3G. Wi-Fi frequency range is 2.4 GHz, WiMAX is 2.5–3.3 GHz, and 4G LTE is 2.99 GHz. The antennas for cellular transmissions are typically located on towers mounted on terraces of houses, apartments or other elevated structures including rooftops and the sides of buildings, and also as a freestanding tower. Typical heights for cell towers are 50–200 feet. Sector antennas for 2G and 3G transmission, broader sector antennas for 4G transmission, and parabolic microwave antennas for point-to-point communications are used in urban and suburban areas (Table 1). There are different types of base stations used by operators in India and they include the macro cell, micro cell, or pico cell. Categorization is based on the purpose of the site rather than in terms of technical constraints such as radiated power or antenna height. In India, macro cellular base station provide the main infrastructure for a mobile phone network and their antennas are mounted at sufficient height to give them a clear view over the surrounding geographical area. The maximum power for individual macro cellular base station transmitter is 20 W. According to FCC (1999), depending on the cell tower height, the majority of cellular base stations in urban and suburban areas operate at an effective radiated power (ERP) of 100 W per channel or less. ERP is a quantity that takes into consideration transmitter power and antenna directivity. An ERP of 100 W corresponds to an actual radiated power of about 5–10 W, depending on the type of antenna used. In urban areas, an ERP of 10 W per channel (corresponding to a radiated power of 0.5–1 W) or less is commonly used. In India, cell tower sites transmit hundreds of watts of power with antenna gain of 50, so ERP sometimes equals 5000 W (Kumar, 2010).

For installation of mobile towers, the standing advisory committee on radio frequency

Table 1: Radio-frequency sources in India.

RF source	Operating frequency	Transmission powers	Numbers
AM towers	540–1600 kHz	100 KW	197 towers
FM towers	88–108 MHz	10 KW	503 towers
TV towers	180–220 MHz	40 KW	1201 towers
Cell towers	800, 900, 1800 MHz	20 W	5.4 lakh towers
Mobile phones	GSM-1800/CDMA GSM-900	1 W 2 W	800+ million
Wi-Fi	2.4–2.5 GHz	10–100 mW	Wi-Fi hot spots

allocations (SACFA) clearances are issued by the wireless monitoring organization, Department of Telecommunications (DoT), after getting no objection from defence and airport authority considering aviation hazards, obstruction to line of sight of existing/planned networks and interferences. In many metros in India, there is no restriction on the location of the towers leading to a situation of overlapping of towers, where even more than 30 cell towers can be seen within 1 km^2.

As mobile technology progresses, the data demands on mobile network increases, coupled with lower costs, their use has increased dramatically and the overall levels of exposure of the population as a whole has increased drastically. Table 2 gives the reference levels for general public exposure adopted by various countries and organizations.

Impacts on Biosystem and Ecosystem

Every living being is tuned into the earth's electromagnetism and uses it for various purposes. A natural mineral magnetite, which is found in living tissues, seems to play an important role. These magnetite crystals are found in bacteria, protozoa, teeth of sea mollusks, fish and sea mammals, eye and beak of birds, and in humans. They are also found in the ethmoid bone above the eye and sinuses and blood-brain barrier (Warnke, 2007). Migratory birds rarely get lost, but sometimes there are disruptions due to storms and magnetic disturbances caused by man (Kirschvink *et al.*, 2001). The traditional and most effective approach to study cause–effect relationships in biological sciences is by experimentation with cells and organisms. The areas of enquiry and experimentation of in vitro studies include genotoxicity, cancer-related gene and protein expression, cell proliferation and differentiation, and apoptosis and in vivo studies include thermal effects, animal behavior, brain biochemistry, neuropathology, teratogenicity, reproduction and development, immune function, blood-brain barrier, visual auditory systems and effects on genetic material, cell function, and biochemistry (Repacholi and Cardis, 2002). In human health studies, concerns have been expressed about the possible interactions of RF-EMF with several human organ systems such as nervous, circulatory, reproductive, and endocrine systems. In order to reveal the global effects of RF-EMF on gene and protein expression, transcriptomics,

Table 2: Reference levels for the general public.

Standards / Country/organization	Power density (W/m^2)	
	900 MHz	**1800 MHz**
ICNIRP, 1998, adopted by India	4.5	9
FCC, 1999	6	10
IEEE, USA, 1999	6	12
Australia	2	2
Belgium	1.1	2.4
Italy	1	1
Israel	x	1
New Zealand	x	0.5
China	x	0.4
Russia	x	0.2
Hungary	0.1	0.1
Toronto Board of Health, Canada, 1999	0.06	0.1
Switzerland	0.04	0.1
France	x	0.1
Germany, ECOLOG, 1998	x	0.09
Austria's precautionary limit	0.001	0.001

and proteomics as high-throughput screening techniques (HTSTs), were eventually employed in EMF research with an intention to screen potential EMF responsive genes and/or proteins without any bias (Nylund and Leszczynski, 2004). The safety standards set by ICNIRP, adopted by India, has only taken into account the short-term effects and not against the biological effects from long-term, non-thermal, low-level microwave exposure from mobile phones, cell phone towers, and many other wireless devices.

Current Research

Various studies have shown that even at low levels of this radiation, there is evidence of damage to cell tissue and DNA, and it has been linked to brain tumors, cancer, suppressed immune function, neuroendocrine disruption, chronic fatigue syndrome, and depression (Rogers, 2002; Milham, 2010). Oncogenesis studies at molecular and cellular levels due to RF-EMF radiations are considered particularly important (Marino and Carrubba, 2009). Orientation, navigation, and homing are critical traits expressed by organisms ranging from bacteria through higher vertebrates. Across many species and groups of organisms, compelling evidence exists that the physical basis of this response is tiny crystals of single-domain magnetite (Fe_3O_4) (Kirschvink *et al.*, 2001). All magnetic field sensitivity in living organisms, including elasmobranch fishes, is the result of a highly evolved, finely-tuned sensory system based on single-domain, ferromagnetic crystals. Animals that depend on the natural electrical, magnetic, and electromagnetic fields for their orientation and navigation through earth's atmosphere are confused by the much stronger and constantly changing artificial fields created by technology and fail to navigate back to their home environments (Warnke, 2007).

Studies on Plants

Tops of trees tend to dry up when they directly face the cell tower antennas and they seem to be most vulnerable if they have their roots close to the water (Belyavskaya, 2004). They also have a gloomy and unhealthy appearance, possible growth delays, and a higher tendency to contract plagues and illnesses. According to Levitt (2010), trees, algae, and other vegetation may also be affected by RF-EMF. Some studies have found both growth stimulation and dieback. The browning of tree tops is often observed near cell towers, especially when water is near their root base. The tree tops are known as RF waveguides. In fact, military applications utilize this capability in trees for low-flying weapon systems. In an observational study, it was found that the output of most fruit-bearing trees reduced drastically from 100% to <5% after 2.5 years of cell tower installation in a farm facing four cell towers in Gurgaon–Delhi Toll Naka (Kumar and Kumar, 2009).

Studies on Insects

Monarch butterflies and locusts migrate great distances using their antennae to sense air currents and earths electromagnetic fields. Moths are drawn to light frequencies. Ants, with the help of their antennas are adept at electrical transmission and found to respond to frequencies as low as 9 MHz. Flying ants are very sensitive to electromagnetic fields (Warnke, 2007).

Bees have clusters of magnetite in the abdominal areas. Colony collapse disorder (CCD) was observed in beehives exposed to 900 MHz for 10 minutes, with sudden disappearance of a hive's inhabitants, leaving only queen, eggs, and a few immature workers behind. With navigational skills affected, worker bees stopped coming to the hives after 10 days and egg production in queen bees dropped drastically to 100 eggs/day compared to 350 eggs (Sharma and Kumar, 2010). Radiation affects the pollinators, honeybees, whose numbers have recently been declining due to CCD by 60% at US West Coast apiaries and 70% along the East Coast (Cane and Tepedino, 2001). CCD is being documented in Greece, Italy, Germany, Portugal, Spain, and Switzerland. Studies performed in Europe documented navigational disorientation, lower honey production, and decreased bee survivorship (Kimmel *et al.*, 2007). EMFs from telecommunication infrastructure interfere with bees' biological clocks that enable them to compensate properly for the sun's movements, as a result of which, may fly in the wrong direction when attempting to return to the hive (Rubin *et al.*, 2006). Bee colonies irradiated with digital enhanced cordless communications (DECT) phones and mobile handsets had a dramatic impact on the behavior of the bees, namely by inducing the worker

piping signal. In natural conditions, worker piping either announces the swarming process of the bee colony or is a signal of a disturbed bee colony (Favre, 2011).

A study by the University of Athens on fruit flies exposed to 6 minutes of 900 MHz pulsed radiation for 5 days showed reduction in reproductive capacity (Panagopoulos *et al.*, 2004). Likewise in 2007, in both 900 and 1800 MHz, similar changes in reproductive capacity with no significant difference between the two frequencies were observed (Panagopoulos *et al.*, 2007). In a third study, it was found it was due degeneration of large numbers of egg chambers after DNA fragmentation (Panagopoulos *et al.*, 2010). When *Drosophila melanogaster* adult insects were exposed to the radiation of a GSM 900/1800 mobile phone antenna at different distances ranging from 0 to 100 cm, these radiations decreased the reproductive capacity by cell death induction at all distances tested (Levengood, 1969).

Studies on Amphibians and Reptiles

Salamanders and turtles have navigational abilities based on magnetic sensing as well as smell. Many species of frogs have disappeared all over the world in the last 3–5 years. Amphibians can be especially sensitive because their skin is always moist, and they live close to, or in water, which conducts electricity easily (Hotary and Robinson, 1994). Toads when exposed to 1425 MHz at a power density of 0.6 mW/cm^2 developed arrhythmia (Levitina, 1966). Increased mortality and induced deformities were noted in frog tadpoles (*Rana temporaria*) (Levengood, 1969). It was observed that experimental tadpoles developed more slowly, less synchronously than control tadpoles, remain at the early stages for a longer time, developed allergies and that EMF causes changes in the blood counts (Grefner *et al.*, 1998). In a two-month study in Spain in common frog tadpoles on the effects of mobile phone mast located at a distance of 140 m noted low coordination of movements, an asynchronous growth, resulting in both big and small tadpoles, and a high mortality (90%) in exposed group. For the unexposed group in Faraday cage, the coordination of movements was normal, the development was synchronous, and a mortality of 4.2% was obtained (Balmori, 2009). In the eggs and embryos of *Rana sylvatica* and *Ambystoma maculatum* abnormalities at several developmental stages were noted such as microcephalia, scoliosis, edema, and retarded growth. Tadpoles developed severe leg malformations and extra legs, as well as a pronounced alteration of histogenesis which took the form of subepidermal blistering and edema. Effects were noted in reproduction, circulatory, and central nervous system, general health and well being (Balmori, 2010; Balmori, 2005).

Studies on Birds

A study by the Centre for Environment and Vocational Studies of Punjab University noted that embryos of 50 eggs of house sparrows were damaged after being exposed to mobile tower radiation for 5–30 minutes (MOEF, 2010). Observed changes included reproductive and coordination problems and aggressiveness. Tower-emitted microwave radiation affected bird breeding, nesting, and roosting in Valladolid, Spain (US Fish & Wildlife Service, 2009). House sparrows, white storks, rock doves, magpies, collared doves exhibited nest and site abandonment, plumage deterioration (lack of shine, beardless rachis, etc.), locomotion problems, and even death among some birds. No symptoms were observed prior to construction of the cell phone towers. According to Balmori, plumage deterioration and damaged feather are the first signs of weakening, illnesses, or stress in birds. The disappearance of insects, leading to lack of food, could have an influence on bird's weakening, especially at the first stages in young bird's life. In chick embryos exposed to ELF pulsed EMR, a potent teratogenic effect was observed, leading to microphthalmia, abnormal trunkal torsion, and malformations on the neural tube (Lahijani and Ghafoori, 2000).

White storks were heavily impacted by the tower radiation during the 2002–2004 nesting season in Spain. Evidence of a connection between sparrow decline in UK and the introduction of phone mast GSM was established (Balmori, 2009). In a study in Spain, the effects of mobile phone mast has been noted in house sparrow (*Passer domesticus*), white stork (*Ciconia ciconia*), reporting problems with reproduction, circulatory, and central nervous system, general health and well-being (microwave syndrome) (Balmori, 2009). Deformities and deaths were noted in the domestic chicken embryos subjected to low-level, non-thermal radiation from the standard 915 MHz cell phone

frequency under laboratory conditions (US Fish & Wildlife Service, 2009). Neural responses of Zebra Finches to 900 MHz radiation under laboratory conditions showed that 76% of the neurons responded by 3.5 times more firings (Beason and Semm, 2002). Eye, beak, and brain tissues of birds are loaded with magnetite, sensitive to magnetic fields, interferes with navigation (Mouritsen and Ritz, 2005).

Studies on Mammals

In a survey of two berry farms in similar habitats in Western Massachusetts (Doyon, 2008), one with no cell phone towers, there were abundant signs of wildlife, migrating and resident birds, bats, small and large mammals, and insects including bees and the other farm with a cell-phone tower located adjacent to the berry patch, virtually no signs of wildlife, tracks, scat, or feathers were noted. The berries on bushes were uneaten by birds and insects and the berries that fell to the ground were uneaten by animals. Whole body irradiation of 20 rats and 15 rabbits at 9.3 GHz for 20 minutes revealed statistically significant changes in cardiac activity (Repacholi *et al.*, 1998). Bradycardia developed in 30% of the cases. Separate ventricular extra systoles also developed. In a study on cows and calves on the effects of exposure from mobile phone base stations, it was noted that 32% of calves developed nuclear cataracts, 3.6% severely. Oxidative stress was increased in the eyes with cataracts, and there was an association between oxidative stress and the distance to the nearest mast (Hässig *et al.*, 2009). It was found that at a GSM signal of 915 MHz, all standard modulations included, output power level in pulses 2 W, specific absorption rate (SAR) 0.4 mW/g exposure for 2 hours, 11 genes were up-regulated and one down-regulated, hence affected expression of genes in rat brain cells (Belyaev *et al.*, 2006). The induced genes encode proteins with diverse functions including neurotransmitter regulation, blood-brain barrier (BBB), and melatonin production.

When rats were exposed for 2 hours a day for 45 days at 0.21 mW/cm^2 power density SAR (0.038 W/kg), a significant decrease in melatonin and increase in both creatine kinase and caspase 3 was found (Kesari *et al.*, 2011). This shows that chronic exposure to these radiations may be an indication of possible tumor promotion. A study on pregnant rats and brains of fetal rats was carried out after irradiating them with different intensities of microwave radiation from cellular phones for 20 days three times a day. Superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), malondialdehyde (MDA), noradrenaline (NE), dopamine (DA), and 5-hydroxyindoleacetic acid (5-HIAA) in the brain were assayed. The significant content differences of noradrenaline and dopamine were found in fetal rat brains (Jing *et al.*, 2012). A study in rabbits exposed to continuous wave and pulsed power at 5.5 GHz found acute effects in the eyes, where lens opacities developed within 4 days (Birenbaum *et al.*, 1969).

Behavioral tasks, including the morris water maze (MWM), radial arm maze, and object recognition task have been extensively used to test cognitive impairment following exposure of rodents to mobile phone radiation (GSM 900 MHz) on various frequencies and SAR values (Fragopoulou *et al.*, 2010). Exposed animals in most of the cases revealed defects in their working memory possibly due to cholinergic pathway distraction. Mobile phone RF-EMF exposure significantly altered the passive avoidance behavior and hippocampal morphology in rats (Narayanan *et al.*, 2010).

With regards to DNA damage or cell death induction due to microwave exposure, in a series of early experiments, rats were exposed to pulsed and continuous-wave 2450 MHz radiation for 2 hours at an average power density of 2 mW/cm^2 and their brain cells were subsequently examined for DNA breaks by comet assay. The authors found a dose-dependent (0.6 and 1.2 W/kg whole body SAR) increase in DNA single-strand and double-strand breaks, 4 hours after the exposure to either the pulsed or the continuous-wave radiation. The same authors found that melatonin and PBN (N-tert-butyl-alpha-phenylnitrone) both known free radical scavengers, block the above effect of DNA damage by the microwave radiation (Lai and Singh, 1995, 1996, 1997). Death in domestic animals like hamsters and guinea pigs were noted (Balmori, 2003). Bats use electromagnetic sensors in different frequencies. Since 1998, a study on a free-tailed bat colony, having *Tadarida teniotis* and *Pipistrellus pipistrellus* has been carried out in Spain and a decrease in number of bats were noted with several phone masts 80 m from the colony. A dead specimen of *Myotis myotis* was found near a small antenna in the city centre (Balmori, 2009).

The most affected of the species are bees, birds, and bats and without these pollinators visiting flowers, 33% of fruits and vegetables would not exist, and as the number of pollinators decline, the agricultural crops will fall short and the price of groceries will go up (Kevan and Phillips, 2001).

Studies on Humans

The exposure to continuous RF-EMF radiation poses a greater risk to children, particularly due to their thinner skulls and rapid rate of growth. Also at risk are the elderly, the frail, and pregnant women (Cherry, 2001). DNA damage via free radical formation inside cells has also been recorded (Lai and Singh, 1996). Free radicals kill cells by damaging macromolecules such as DNA, protein, and membrane are carcinogenic. In fact, EMR enhances free radical activity. Single- and double-strand DNA breaks are seen in rat brain cells after acute exposure to radiofrequency electromagnetic radiation. Kane (2001) denotes that RF-EMF radiations lead to tissue damage, DNA damage, or chromosome mutations. In 2008, the Austrian Department of Health found a higher risk of cancer among people living within 200 m of a mobile phone base station and that cancer risk rose with increasing exposure, reaching 8.5 times the norm for people most exposed. From a study on in vitro cell response to mobile phone radiation (900 MHz GSM signal) using two variants of human endothelial cell line, it was suggested that the cell response to mobile phone radiation might be genome- and proteome-dependent. Therefore, it is likely that different types of cells and from different species might respond differently to mobile phone radiation or might have different sensitivity to this weak stimulus (Nylund and Leszczynski, 2006).

The results of the Interphone, an international case–control study to assess the brain tumor risk in relation to mobile telephone use, reveals no overall increase in risk of glioma or meningioma but there were suggestions of an increased risk of glioma at the highest exposure levels (30 minutes per day of cell phone use for 8–10 years) and ipsilateral exposures (ICNIRP, 2011). Children and young adults were excluded from the study and a separate study called Mobi-Kids is underway. According to Santini *et al.* (2002), comparisons of complaints in relation with distance from base station show significant increase as compared to people living greater than 300 m or not exposed to base station, till 300 m for tiredness, 200 m for headache, sleep disturbance, and discomfort, and 100 m for irritability, depression, loss of memory, dizziness, and libido decrease. Women significantly more often than men complained of headache, nausea, loss of appetite, sleep disturbance, depression, discomfort, and visual perturbations (Santini *et al.*, 2002). According to Oberfeld *et al.* (2004) in Spain, a follow-up study found that the most exposed people had a higher incidence of fatigue, irritability, headaches, nausea, loss of appetite, sleeping disorders, depression, discomfort, difficulties concentrating, memory loss, visual disorders, dizziness, and cardiovascular problems. Women are more at risk as they tend to spend more time at home and are exposed to radiation continuously. The authors recommended a maximum exposure of 0.0001 $\mu W/cm^2$ or 0.000001 W/m^2. There was prevalence of neuropsychiatric complaints among people living near base stations (Abdel-Rassoul *et al.*, 2007). Urban electromagnetic contamination (electrosmog) 900 and 1800 MHz pulsated waves interfere in the nervous system of living beings (Hyland, 2000). Growing amounts of published research show adverse effects on both humans and wildlife far below a thermal threshold, usually referred to as “non-thermal effects”, especially under conditions of long-term, low-level exposure (Levitt and Lai, 2010).

Australian research conducted by De Iuliis *et al.* (2009) by subjecting in vitro samples of human spermatozoa to radio-frequency radiation at 1.8 GHz and SAR of 0.4–27.5 W/kg showed a correlation between increasing SAR and decreased motility and vitality in sperm, increased oxidative stress and 8-Oxo-2′-deoxyguanosine markers, stimulating DNA base adduct formation and increased DNA fragmentation. GSM mobile phone exposure can activate cellular stress response in both humans and animal cells and cause the cells to produce heat shock proteins (HSP27 and HSP70) (Leszczynski, 2002). HSPs inhibit natural programmed cell death (apoptosis), whereby cells that should have committed suicide continue to live. Recent studies have shown that these HSPs inhibit apoptosis in cancer cells. In several cases, melatonin hormone which controls the daily biological cycle and has an oncostatic action, produced by the epiphysis (pineal gland) in mammals, mainly during the night, is found to reduce the action of EMR exposure, but the synthesis of melatonin itself seems to be reduced

by EMR (Panagopoulos *et al.*, 2008). In a study to observe the effects of melatonin in hormone balance in a diabetic, it was found that melatonin caused reduction in serum insulin, serum cortisol, serum ACTH, and serum TSH levels while increase in serum gastrin level. Of the biochemical parameters, melatonin caused reductions in TLC, LDLC, and FBS while increase in HDLC. It also caused reduction in neutrophil and increase in lymphocyte count in a diabetic with increase in faecal fat excretion (Mitra and Bhattacharya, 2008).

RF-EMR produces DNA damage via free radical formation inside cells. Free radicals kill cells by damaging macromolecules such as DNA, protein, and membrane, also shown to be carcinogenic. EMR enhances free radical activity. EMR interferes with navigational equipments, lifeline electronic gadgets in hospitals, and affects patients with pacemakers. A short-term exposure (15 and 30 minutes) to RFR (900 MHz) from a mobile phone caused a significant increase in DNA single strand breaks in human hair root cells located around the ear which is used for the phone calls (Çam and Seyhan, 2012). Various in vitro studies have shown that 1800 MHz RF-EMF radiation could cause oxidative damage to mtDNA in primary cultured neurons. Oxidative damage to mtDNA may account for the neurotoxicity of RF radiation in the brain (Xu *et al.*, 2010).

Studies carried out on the RF levels in North India, particularly at the mobile tower sites at Delhi have shown that people in Indian cities are exposed to dangerously high levels of EMF pollution (Tanwar, 2006). An independent study was commissioned by the Cellular Operators Association of India (COAI) and Association of Unified Telecom Service Providers of India (AUSPI) as a proactive measure stemming from the concern for the public health and safety issues on electromagnetic radiation measurement at New Delhi showed compliance with ICNIRP standards. 180 areas were studied across the capital to understand the extent of RF-EMF radiations emitting from the mobile towers, revealed that the readings were 100 times below international safety guidelines. The study measured cumulative emissions within the 800–2000 MHz band of frequency (which includes both GSM and CDMA technologies) across in the nation's capital using carefully calibrated equipment, as per the DoT prescribed procedure in line with the ICNIRP specifications. In a similar, but independent case study in Mumbai, it was found that people living within 50–300 m radius are in the high radiation zone and are more prone to ill-effects of electromagnetic radiation. Four cases of cancer were found in three consecutive floors (6th, 7th, 8th) directly facing and at similar height as four mobile phone towers placed at the roof of the opposite building (Kumar, 2010). According to the Seletun Scientific Statement (2011), low-intensity (non-thermal) bioeffects and adverse health effects are demonstrated at levels significantly below existing exposure standards. ICNIRP/WHO and IEEE/FCC public safety limits are inadequate and obsolete with respect to prolonged, low-intensity exposures (New International EMF Alliance, 2011). New, biologically-based public exposure standards are urgently needed to protect public health world-wide. EMR exposures should be reduced now rather than waiting for proof of harm before acting (Fragopoulou *et al.*, 2010).

Electrohypersensitivity (EHS) and Electromagnetic Field Intolerance (EFI) Syndrome

Electrosensitivity of people is now recognized as a physical impairment by government health authorities in the United Kingdom and Sweden. The UK Health Protection Agency (HPA) recognized that people can suffer nausea, headaches, and muscle pains when exposed to electromagnetic fields from mobile phones, electricity pylons, and computer screens. A case study in Sweden, one of the first countries where mobile technology was introduced approximately 15 years ago, shows that 250,000 Swedes are allergic to mobile phone radiation. Sweden has now recognized EHS as a physical degradation and EHS sufferers are entitled to have metal shielding installed in their homes free of charge from the local government (Kumar, 2010; Johansson, 2010).

Belpomme (2011) in his presentation at the 8th National Congress on Electrosmog in Berne in 2011 elaborates on the dangers of wireless technology and the diagnostics and treatment of the electromagnetic field intolerance (EFI) Syndrome. In his study from 2008 to 2011, the patients with EHS were investigated with a pulse equilibrium brain scan, dosage of histamine in the blood, dosage of the heat shock proteins HSP70 and HSP27, and appearance and disappearance of symptoms on exposure to an electromagnetic field source. Diagnosis of fatigue and depression were noted. The physiological changes such as vitamin D deficiency, decrease in heat

shock proteins, increase in histamines, increase in biomarker of the opening of blood-brain barrier, protein S100P, decrease in urinary melatonin, and increase in blood anti-myelin proteins were noted in the electrosensitives. Around 50% of the patients in the study had used a mobile phone for more than one hour per day during several years and his findings were similar to the figures published by Hardell's study (2007) dealing with the cancer occurrences and electromagnetic fields.

Future Challenges and Solutions

Research into the advantages of radio-frequency energies seen in tissue heating in benign prostatic hyperplasia (BPH), electrical therapy for cardiac arrhythmia, radio-frequency ablation, use of 41.5–44.5°C temperature to kill tumors, shortwave and microwave diathermy for musculoskeletal injuries, and microwave oven used in food preparation are all carried out under controlled conditions. But effects, if any, from RF-EMF radiations released into the environment over a long period of time in densely populated areas where people are continuously exposed to them will show in years to come. According to Osepchuk (1983), frequencies used in industrial, scientific, and medical heating processes are 27.12, 40.68, 433, 915, 2450, and 5800 MHz. Out of which, for diathermy, frequencies used are 27.12, 915, and 2450 MHz in US and 433 MHz is authorized in Europe. According to Kasevich (2000), "the physics of electromagnetic waves and their interactions with material and biological systems is based on the concept that the electromagnetic wave is a force field which exerts a mechanical torque, pressure or force on electrically charged molecules. All living things contain these dielectric properties. The thermal effects produced by absorption of electromagnetic energy are the direct result of water molecules acted upon by the oscillating electric field, rubbing against each other to produce electric heat (thermal effects)". Research work on electromagnetic bioeffects in humans and animals in the non-thermal range is continuing where effects are noted even at intensities lower than 1 mW/m^2 (0.001 W/m^2 or 1000 μW/m^2, 0.0001 mW/cm^2 or 0.1 μW/cm^2).

According to Levitt (2007), adverse outcomes of pregnancy can be mutagenic, teratogenic, oncogenic or carcinogenic, and ionizing radiations can cause all three. In animal studies, non-ionizing radiation was also found to be teratogenic and oncogenic, and likely mutagenic, but it is unclear if these observations were due to heating affect, non-thermal affects or both. Trees, plants, soil, grass, and shrubs have the ability to absorb electromagnetic wave energy over a very broad range of wavelengths. According to the resonance concept, human beings can act as receiving antennas for some frequencies, where the absorbed energy is maximized in some areas of the body, like the brain (Levitt, 2007).

In the Bioinitiative Report, a document prepared by 14 international experts in a nine-month project, in which over 2000 scientific studies were reviewed, Sage (2007) came to a conclusion that there may be no lower limit that may be safe, and there was a need for biologically-based limits (1 mW/m^2 or 0.001 W/m^2) and children are at most risk. Safety limits suggested are 0.001 W/m^2 for outdoor cumulative radio-frequency exposure and 0.0001 W/m^2 for indoor, cumulative radio-frequency exposure. According to Blank (2012), there is a need for a realistic biological standard to replace the thermal (SAR) standard. The precautionary approaches includes prudence avoidance for public and ALARA, which stands for "as low as reasonably attainable" for regulatory agencies.

According to Havas (2006), several disorders, including asthma, ADD/ADHD, diabetes, multiple sclerosis, chronic fatigue, fibromyalgia, are increasing at an alarming rate, as is electromagnetic pollution in the form of dirty electricity, ground current, and radio-frequency radiation from wireless devices and the connection between electromagnetic pollution and these disorders needs to be investigated and the percentage of people sensitive to this form of energy needs to be determined. According to Milham (2010), 20th century epidemic of the so-called diseases of civilization, including cardiovascular disease, cancer, diabetes, and also suicides, was caused by electrification and the unique biological responses we have to it and that our evolutionary balance, developed over the millennia has been severely disturbed and disrupted by man-made EMFs.

Conclusion

The Department of Telecommunication (DoT) in India has set new norms for cell phone towers with effect from September 1, 2012 (The Hindu, 2012). Exposure standards for RF-EMF radiation has been reduced to one-tenth of the existing level and SAR from 2 to 1.6 W/kg. This came after the Ministry of Environment and Forests

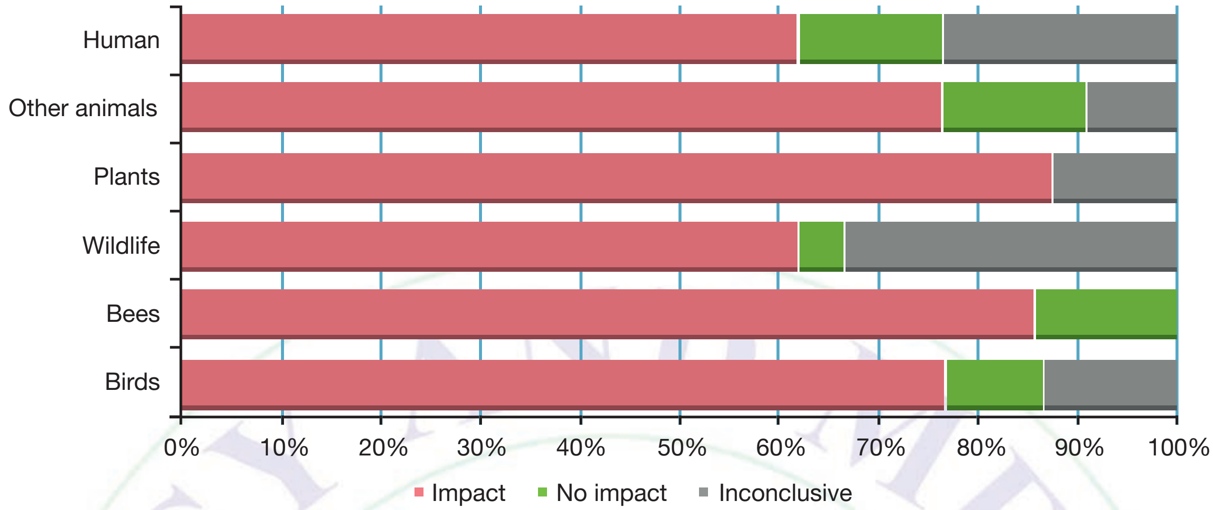


Figure 2: Percentage of studies that reported harmful effect of EMR in various groups of organisms ($n = 919$), MOEF Report (2010).

(MOEF) set up an Inter-Ministerial Committee (IMC) to study the effects of RF-EMF radiations on wildlife (Figure 2) and concluded that out of the 919 research papers collected on birds, bees, plants, other animals, and humans, 593 showed impacts, 180 showed no impacts, and 196 were inconclusive studies. They conclude that there are no long-term data available on the environmental impacts of RF-EMF radiations in India. The population of India is increasing as well as the cell phone subscribers and the cell towers as supporting infrastructure. Hence, there is an urgent need to fill the gaps and do further research in this field with emphasis on the effects of early life and prenatal RF-EMF radiation exposure in animals, dosimetry studies, cellular studies using more sensitive methods, and human epidemiological studies, especially on children and young adults on behavioral and neurological disorders and cancer. Meanwhile, one can take the precautionary principle approach and reduce RF-EMF radiation effects of cell phone towers by relocating towers away from densely populated areas, increasing height of towers or changing the direction of the antenna.

References

Abdel-Rassoul G, El-Fateh OA, Salem MA, Michael A, Farahat F, El-Batanouny M, *et al.*, 2007. Neurobehavioral effects among inhabitants around mobile phone base stations. Neurotoxicology, 28(2): 434–440.

ARPANSA, 2011. Introduction to radiation basics. http://www.arpansa.gov.au/RadiationProtection/basics/index.cfm

Balmori A, 2003. The effects of microwave radiation on the wildlife. Preliminary results, Valladolid (Spain). http://www.whale.to/b/martinez.pdf

Balmori A, 2005. Possible effects of electromagnetic fields from phone masts on a population of white stork (*Ciconia ciconia*). Electromagnetic Biology and Medicine, 24: 109–119.

Balmori A, 2009. Electromagnetic pollution from phone masts. Effects on wildlife. Pathophysiology, 16(2): 191–199. DOI: 10.1016/j.pathophys.2009.01.007

Balmori A, 2010. Mobile phone masts effects on common frog (*Rana temporaria*) tadpoles: the city turned into a laboratory. Electromagnetic Biology and Medicine, 29: 31–35.

Barnes FS, Greenebaum B, 2007. Handbook of biological effects of electromagnetic fields: bioengineering and biophysical aspects of electromagnetic fields. 3rd Edition, Boca Raton, FL: CRC Taylor and Francis Press, 440.

Beason RC, Semm P, 2002. Responses of neurons to an amplitude modulated microwave stimulus. Neuroscience Letters, 333: 175–178.

Belpomme D, 2011. Presentation of Prof. Dominique Belpomme at 8th National Congress on Electrosmog, Berne. http://citizensforsafetechnology.org/uploads/scribd/Presentation%20of%20Prof.pdf

Belyaev IY, Koch CB, Terenius O, Roxström-Lindquist K, Malmgren LO, Sommer W, *et al.*, 2006. Exposure of rat brain to 915 MHz GSM microwaves induces changes in gene expression but not double stranded DNA breaks or effects on chromatin conformation. Bioelectromagnetics, 27(4): 295–306.

Belyavskaya NA, 2004. Biological effects due to weak magnetic field on plants. Advances in Space Research, 34(7): 1566–1574.

Birenbaum L, Grosof GM, Rosenthal SW, Zaret MM, 1969. Effect of microwaves on the eye. IEEE Transactions on Biomedical Engineering, 16(1): 7–14.

Blank M, 2012. Cell Towers and Cancer – Bioinitiative Report. http://www.youtube.com/watch?v=a6wLFeIrCtU&feature=related; www.weepinitiative.org

Business Standard, 2010. Cellular tower study debunks radiation myth by COAI, AUSPI. December 21, 2010. http://www.business-standard.com/india/news/cellular-tower-study-debunks-radiation-myth-by-coai-auspi/419036

Çam ST, Seyhan N, 2012. Single-strand DNA breaks in human hair root cells exposed to mobile phone radiation. International Journal of Radiation Biology, 88(5): 420–424.

Cane JH, Tepedino VJ, 2001. Causes and extent of declines among native North American invertebrate pollinators: detection, evidence, and consequences. Conservation Ecology, 5(1): 1.

Cherry N, 2001. Evidence that electromagnetic radiation is genotoxic: the implications for the epidemiology of cancer and cardiac, neurological, and reproductive effects. http://www.neilcherry.com/documents/90_m2_EMR_Evidence_That_EMR-EMF_is_genotoxic.pdf

Davis D, 2010. Disconnect. USA: Dutton Penguin Group, 69–95.

De Iuliis GN, Newey RJ, King BV, Aitken RJ, 2009. Mobile phone radiation induces reactive oxygen species production and DNA damage in human spermatozoa in vitro. PLoS ONE, 4(7): e6446.

DoT, 2010. Report of the Inter-Ministerial Committee (IMC) on EMF radiation. Ministry of Communication and Information Technology, Government of India. http://www.dot.gov.in/miscellaneous/IMC%20Report/IMC%20Report.pdf

Doyon PR, 2008. Are the microwaves killing the insects, frogs, and birds? And are we next? http://www.thenhf.com/article.php?id=480

Favre D, 2011. Mobile phone-induced honeybee worker piping. Apidologie, 42(3): 270–279. DOI: 10.1007/s13592-011-0016-x

FCC, 1999. Questions and answers about biological effects and potential hazards of radiofrequency electromagnetic fields. OET Bulletin 56, 4th Edition. http://www.fcc.gov/encyclopedia/oet-bulletins-line

Fragopoulou A, Grigoriev Y, Johansson O, Margaritis LH, Morgan L, Richter E, *et al.*, 2010. Scientific panel on electromagnetic field health risks: consensus points, recommendations, and rationales. Reviews on Environmental Health, 25(4): 307–317.

Grefner NM, Yakovleva TL, Boreysha IK, 1998. Effects of electromagnetic radiation on tadpole development in the common frog (*Rana temporaria* L.). Russian Journal of Ecology, 29(2): 133–134.

Hardell L, Carlberg M, Söderqvist F, Mild KH, Morgan LL, 2007. Long-term use of cellular phones and brain tumours: increased risk associated with use for > or = 10 years. Occupational and Environmental Medicine, 64(9): 626–632.

Hässig M, Jud F, Naegeli H, Kupper J, Spiess BM, 2009. Prevalence of nuclear cataract in Swiss veal calves and its possible association with mobile telephone antenna base stations. Schweizer Archiv fur Tierheilkde, 151(10): 471–478.

Havas M, 2006. Electromagnetic hypersensitivity: biological effects of dirty electricity with emphasis on diabetes and multiple sclerosis. Electromagnetic Biology and Medicine, 25: 259–268.

Hotary KB, Robinson KR, 1994. Endogenous electrical currents and voltage gradients in Xenopus embryos and the consequences of their disruption. Developmental Biology, 166: 789–800.

Hyland GJ, 2000. Physics and biology of mobile telephony. The Lancet, 356: 1833–1836.

ICNIRP SCI Review, 2011. Mobile phones, brain tumors, and the Interphone study: Where are we now? Environmental Health Perspectives, 119(11): 1534–1538.

ICNIRP, 1998. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Physics, 74(4): 494–522.

Instituto Edumed, 2010. Latin American experts committee on high frequency electromagnetic fields and human health, Non-ionizing electromagnetic

radiation in the radio-frequency spectrum and its effects on human health. www.edumed.org.br/lasr2008/en/

Jing J, Yuhua Z, Xiao-qian Y, Rongping J, Dong-mei G, Xi C, 2012. The influence of microwave radiation from cellular phone on fetal rat brain. Electromagnetic Biology and Medicine, 31(1): 57–66.

Johansson O, 2010. Aspects of studies on the functional impairment electrohypersensitivity. IOP Conference Series: Earth and Environmental Science, 10: 012005. DOI:10.1088/1755-1315/10/1/012005

Kane RC, 2001. Cellular telephone russian roulette – a historical and scientific perspective. New York: Vantage Press.

Kasevich RS, 2000. Cell Towers, Wireless Convenience or Environmental Hazards? Proceedings of the "Cell Towers Forum" State of the Science/State of the Law. Chapter 11, Levitt BB (Ed.), Canada: New Century Publishing, pp. 170–175.

Kesari KK, Kumar S, Behari J, 2011. Biomarkers inducing changes due to microwave exposure effect on rat brain, pp. 1–4. http://www.academia.edu/967270/Biomarkers_inducing_changes_due_to_microwave_exposure_effect_on_rat_brain

Kevan PG, Phillips TP, 2001. The economic impacts of pollinator declines: an approach to assessing the consequences. Ecology and Society, 5(1): 8.

Kimmel S, Kuhn J, Harst W, Stever H, 2007. Effects of electromagnetic exposition on the behavior of the honeybee (*Apis mellifera*). Environmental Systems Research, 8: 1–8.

Kirschvink JL, Walker MM, Diebel CE, 2001. Magnetite-based magnetoreception. Current Opinion in Neurobiology, 11: 462–467.

Kumar G, 2010. Report on cell tower radiation, submitted to the Secretary, DoT, Delhi. http://www.ee.iitb.ac.in/~mwave/GK-cell-tower-rad-report-DOT-Dec2010.pdf

Kumar N, Kumar G, 2009. Biological effects of cell tower radiation on human body. Electrical engineering department, IIT Bombay. December 16–19, ISMOT, 2009, New Delhi, India.

Lahijani MS, Ghafoori M, 2000. Teratogenic effects of sinusoidal extremely low frequency electromagnetic fields on morphology of 24 hr chick embryos. Indian Journal of Experimental Biology, 38(7): 692–699.

Lai H, Singh NP, 1995. Acute low-intensity microwave exposure increases DNA single-strand breaks in rat brain cells. Bioelectromagnetics, 16: 207–210.

Lai H, Singh NP, 1996. Single- and double-strand DNA breaks in rat brain cells after acute exposure to radio-frequency electromagnetic radiation. International Journal of Radiation Biology, 69: 513–521.

Lai H, Singh NP, 1997. Melatonin and a spin-trap compound block radio-frequency electromagnetic radiation-induced DNA strand breaks in rat brain cells. Bioelectromagnetics, 18: 446–454.

Leszczynski D, Joenväärä S, Reivinen J, Kuokka R, 2002. Non-thermal activation of the hsp27/p38MAPK stress pathway by mobile phone radiation in human endothelial cells: molecular mechanism for cancer- and blood-brain barrier–related effects. Differentiation, 70: 120–129.

Levengood WC, 1969. A new teratogenic agent applied to amphibian embryos. Journal of Embryology and Experimental Morphology, 21(1): 23–31.

Levitina NA, 1966. Non-thermal effect of microwaves on the rhythm of cardiac contractions in the frog. Bulletin of Experimental Biology and Medicine, 62(12): 64–66.

Levitt BB, 2007. Electromagnetic fields: a consumer's guide to the issues and how to protect ourselves. Authors Guild Backinprint.com Edition, iUniverse, Inc. ISBN: 978-0-595-47607-7.

Levitt BB, 2010. The environmental effects of wireless technologies and other sources of non-ionizing radiation: an overview. http://www.croww.org/environmental-effects.pdf

Levitt BB, Lai H, 2010. Biological effects from exposure to electromagnetic radiation emitted by cell tower base stations and other antenna arrays. Canada: NRC Research Press, 369–395.

Marino AA, Carrubba A, 2009. The effects of mobile phone electromagnetic fields on brain electrical activity: A critical review of literature. Electromagnetic Biology and Medicine, 28(3): 250-274. http://andrewamarino.com/PDFs/CellphoneEMFs-Review.pdf

Milham S, 2010. Historical evidence that electrification caused the 20th century epidemic of disease of civilization. Medical Hypotheses, 74(2): 337–345.

Mitra A, Bhattacharya D, 2008. Effects of melatonin in mild diabetics with dyslipidaemia. Journal of Human Ecology, 23(2): 109–114.

MOEF, 2010. Report on possible impacts of communication towers on wildlife, including birds and bees, Government of India. http://www.indiaenvironmentportal.org.in/files/file/final_mobile_towers_report.pdf

Mouritsen H, Ritz T, 2005. Magnetoreception and its use in bird navigation. Current Opinion in Neurobiology, 15(4): 406–414.

Narayanan SN, Kumar RS, Potu BK, Nayak S, Bhat PG, Mailankot M, 2010. Effect of radio-frequency electromagnetic radiations (RF-EMR) on passive avoidance behaviour and hippocampal morphology in Wistar rats. Uppsala Journal of Medical Sciences, 115: 91–96.

New International EMF Alliance, 2011. Seletun Statement, Oslo, Norway. http://iemfa.org/index.php/publications/seletun-resolution

Nylund R, Leszczynski D, 2004. Proteomics analysis of human endothelial cell line EA.hy926 after exposure to GSM 900 radiation. Proteomics, 4: 1359–1365.

Nylund R, Leszczynski D, 2006. Mobile phone radiation causes changes in gene and protein expression in human endothelial cell lines and the response seems to be genome- and proteome-dependent. Proteomics, 6: 4769–4780.

Oberfeld G, Navarro E, Portoles M, Maestu C, Gomez-Perretta C, 2004. The microwave syndrome – further aspects of a Spanish study. EBEA Congres Kos-Greece, 1: 1–9.

Osepchuk JM, 1983. Biological Effects of Electromagnetic Radiation. New York, USA: John Wiley and Sons, IEEE INC.

Panagopoulos DJ, Karabarbounis A, Margaritis LH, 2004. Effect of GSM 900 MHz mobile phone radiation on the reproductive capacity of *Drosophila melanogaster*. Electromagnetic Biology and Medicine, 23(1): 29–43.

Panagopoulos DJ, Karabarbounis A, Margaritis LH, 2008. Mobile Telephony Radiation Effects on Living Organisms. In: mobile telephones, Chapter 3, Harper AC, Buress RV (Eds.). New York: Nova Science Publishers, pp. 107–149.

Panagopoulos DJ, Chavdoula ED, Nezis IP, Margaritis LH, 2007. Cell death induced by GSM 900 MHz and DCS 1800 MHz mobile telephony radiation. Mutation Research, 626(1–2): 69–78.

Panagopoulos DJ, Chavdoula ED, Margaritis LH, 2010. Bioeffects of mobile telephony radiation in relation to its intensity or distance from the antenna. International Journal of Radiation Biology, 86(5): 345–357.

Repacholi MH, Cardis E, 2002. Criteria for EMF health risk assessment. Radiation Protection Dosimetry, 72: 305–312.

Repacholi MH, Rubtsova NB, Muc AM, 1998. Proceedings of the International Meeting on "Electromagnetic Fields: Biological Effects and Hygienic Standardization", Moscow. Geneva, Switzerland: World Health Organisation, 1999. http://www.who.int/iris/handle/10665/65976

Rogers KJ, 2002. Health effects from cell phone tower radiation. http://www.scribd.com/doc/3773284/Health-Effects-from-Cell-Phone-Tower-Radiation

Rubin EB, Shemesh Y, Cohen M, Elgavish S, Robertson HM, Bloch G, 2006. Molecular and phylogenetic analyses reveal mammalian-like clockwork in the honey bee (*Apis mellifera*) and shed new light on the molecular evolution of the circadian clock. Genome Research, 16(11): 1352–1365.

Sage C, 2007. The Bioinitiative Report and Biologically-based Exposure Standards. http://www.youtube.com/watch?v=jC6Bzz25rzU&feature=relmfu

Santini R, Santini P, Danze JM, Le Ruz P, Seigne M, 2002. Investigation on the health of people living near mobile telephone relay stations: incidence according to distance and sex. Pathological Biology (Paris), 50(6): 369–373.

SCENIHR, 2007. Possible effects of electromagnetic fields (EMF) on human health. 16th Plenary on 21st March 2007. http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_007.pdf

Sharma VP, Kumar NR, 2010. Changes in honeybee behaviour and biology under the influence of cellphone radiations. Current Science, 98(10): 1376–1378.

Tanwar VS, 2006. Living Dangerously in Indian cities: an RF radiation pollution perspective. ElectroMagnetic Interference and Compatibility (INCEMIC), 2006 Proceedings of the 9th International Conference, Cogent EMR Solutions, New Delhi, India, pp. 458–466.

The Hindu, 2012. Mobile base station radiation limit will be cut from September 1. August 27, 2012. http://www.thehindu.com/news/national/article3828735.ece

The Hindu, 2012. No major health fallout from typical exposure, say studies. August 28, 2012. http://www.thehindu.com/todays-paper/tp-national/article3829594.ece

TRAI, 2012. Indian telecom services performance indicator report for the quarter ending December. Information note to the Press. Press release No. 74/2012, New Delhi. www.trai.gov.in

US Fish & Wildlife Service, 2009. Public Press release on briefing paper on the need for research into the cumulative impacts of communication towers on migratory birds and other wildlife in

the United States, Division of Migratory Bird Management (DMBM). http://electromagnetichealth.org/pdf/CommTowerResearchNeedsPublicBriefing-2-409.pdf

Warnke U, 2007. Bees, birds, and mankind: destroying nature by "Electrosmog". Effects of mobile radio and wireless communication. A series of papers by the competence initiative for the protection of mankind, environment, and democracy. Kempten. http://www.hese-project.org/hese-uk/en/papers/warnke_bbm.pdf

WHO Press Release, 2011. IARC classifies radiofrequency electromagnetic fields as possibly carcinogenic to humans. International Agency for Research on Cancer (IARC). http://www.who.int/mediacentre/factsheets/fs193/en

Xu S, Zhou Z, Zhang L, Yu Z, Zhang W, Wang Y, *et al.*, 2010. Exposure to 1800 MHz radio-frequency radiation induces oxidative damage to mitochondrial DNA in primary cultured neurons. Brain Research, 1311: 189–196.

5G; 5G wireless telecommunications expansion: Public health and environmental implications, Environmental Research.
(Dr. Cindy Russell MD.); 2018

Environmental Research 165 (2018) 484–495

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

5 G wireless telecommunications expansion: Public health and environmental implications☆

Cindy L. Russell

PO Box 7443, Menlo Park, CA 94026, USA

ARTICLE INFO

Keywords:
Wireless technology
Public health
Radiofrequency radiation
Environmental pollution

ABSTRACT

The popularity, widespread use and increasing dependency on wireless technologies has spawned a telecommunications industrial revolution with increasing public exposure to broader and higher frequencies of the electromagnetic spectrum to transmit data through a variety of devices and infrastructure. On the horizon, a new generation of even shorter high frequency 5G wavelengths is being proposed to power the Internet of Things (IoT). The IoT promises us convenient and easy lifestyles with a massive 5G interconnected telecommunications network, however, the expansion of broadband with shorter wavelength radiofrequency radiation highlights the concern that health and safety issues remain unknown. Controversy continues with regards to harm from current 2G, 3G and 4G wireless technologies. 5G technologies are far less studied for human or environmental effects.

It is argued that the addition of this added high frequency 5G radiation to an already complex mix of lower frequencies, will contribute to a negative public health outcome both from both physical and mental health perspectives.

Radiofrequency radiation (RF) is increasingly being recognized as a new form of environmental pollution. Like other common toxic exposures, the effects of radiofrequency electromagnetic radiation (RF EMR) will be problematic if not impossible to sort out epidemiologically as there no longer remains an unexposed control group. This is especially important considering these effects are likely magnified by synergistic toxic exposures and other common health risk behaviors. Effects can also be non-linear. Because this is the first generation to have cradle-to-grave lifespan exposure to this level of man-made microwave (RF EMR) radiofrequencies, it will be years or decades before the true health consequences are known. Precaution in the roll out of this new technology is strongly indicated.

This article will review relevant electromagnetic frequencies, exposure standards and current scientific literature on the health implications of 2G, 3G, 4G exposure, including some of the available literature on 5G frequencies. The question of what constitutes a public health issue will be raised, as well as the need for a precautionary approach in advancing new wireless technologies.

1. Introduction

The adoption of new 5G technology promises to give the public a transformative communication network with an explosion of speed, volume of data and number of devices with unlimited computing instantly to anyone in the world. High tech companies are already marketing the Internet of Things to businesses, healthcare systems, schools and the public. The promise to connect our phones and appliances, will virtually eliminate many day-to-day household and business functions including driving. This will, according to industry, create a superior, connected society and unprecedented economic growth. What is missing in this discussion is the maturing literature on adverse biological, physiological, and psychological health effects of the 2G, 3G, and 4G radiofrequencies we are already exposed to, in addition to indications from the scientific literature that 5G frequencies could also be hazardous.

Many important but unanswered questions merit serious consideration. Is the widespread deployment of this pervasive higher frequency small cell distributed antennae system in our cities and on our homes safe for humans and the environment? Will it add to the burden of chronic disease that costs our nation, according to the CDC, an estimated 2.3 trillion dollars annually (CDC, 2017)? Are we already digitally over connected, shrinking our gray matter and becoming a dysfunctional addicted nation because of it (Weng et al., 2012)? How

☆ The author has read and approved the paper and it has not been published previously nor is it being considered by any other peer-reviewed journal. The author has no conflicts of interest. There was no financial support for the research, design, analysis, interpretation or writing of this article nor for the decision to publish this article.

E-mail address: cindyleerussell@gmail.com.

https://doi.org/10.1016/j.envres.2018.01.016
Received 3 October 2017; Accepted 16 January 2018
Available online 11 April 2018

will this affect our privacy, cyber security and the security of our medical records? Will physicians be able to recognize the emerging adverse health effects of new millimeter technology let alone that of current wireless devices? These important questions have not been addressed, yet industry and government policy have already moved forward with advertising, manufacturing and legislating the adoption of these new technologies.

2. Methods

A review of the literature was performed which included health effects of wireless technologies, controversies related to radiofrequency health effects, telecommunications 5G innovations and specifications for wireless technology as well as related policies affecting public health.

3. Results

3.1. Controversy persists as evidence of harm increases

The controversy over health effects of radiofrequency electromagnetic radiation (RF EMR) from commonly used wireless devices such as cell phones, cordless phones, WiFi routers and cell tower infrastructure remains problematic. RF research in the U.S. is poorly funded and even when a study is robust it never seems to answer the question of long term safety or provide appropriate precautionary limits. (Wyde, 2016). In 2011 the International Agency on Research on Cancer (IARC) listed non-ionizing radiofrequency radiation from cell phones and other wireless devices in Group 2B: Possibly carcinogenic to humans, based on a thorough analysis of current scientific evidence (IARC, 2011; IARC, 2017). Some researchers feel this listing should be changed to a Group 2A: Probably carcinogenic to humans or to Group 1: Carcinogenic to humans classification (Morgan et al., 2015; Sage and Carpenter, 2012). This is based on the recent National Toxicology Program Carcinogenicity Studies of Cell Phone Radiofrequency Radiation that report a significant increase in heart and brain tumors with RF-EMR exposure (Wyde, 2016). This is in addition to the abundance of basic scientific studies that show a clear health risk associated with exposure to radiofrequencies, especially with long term exposure (Hardell et al., 2013a, 2013b; Adams et al.al., 2014; Bortkiewicz et al., 2017; Carlberg and Hardell, 2017; Hassanshahi et al., 2017; Liu et al., 2014; Levitt and Lai, 2010). Many of these studies demonstrate effects well below the heat threshold of current safety standards (Wyde, 2016; IARC, 2011; Sage and Carpenter, 2012; EPA, 1992; Esmekaya et al., 2011; Grigoriev et al., 2010; Belyaev, 2005; Yu and Yao, 2010). Radiofrequencies are absorbed by and pass through living systems that contain water. Pregnant women and children are more vulnerable to developmental harm from microwave radiation due to immature organ systems (Birks et al., 2017; Othman et al., 2017a, 2017b). Research also shows children absorb more microwave radiation per body weight than an adult, however, standards were developed for adult bodies (Morgan et al., 2014).

3.1.1. Industry bias and scientific results

Industry continues to state that the weight of evidence regarding harm from RF-EMR is inconclusive. Studies that review the sources of funding and scientific bias regarding cell phones and brain cancer indicate otherwise. Huss et al. (2007) performed a systematic review regarding the association of cell phone use and brain tumors in relation to funding. He found that industry studies showed a positive association 33% of the time, whereas non-industry studies showed an 82% association. In addition, they discovered that none of the 31 peer reviewed journals listed conflicts of interest for the authors.

Myung et al. (2009) performed a meta-analysis and found that there was a small but significant elevation in brain tumors with long term cell phone use when high quality studies were examined. He noted Hardell's research to be more robust, as "all of the studies by Hardell et al. used blinding to the status of patient cases or controls at the interview and were categorized as having a high methodologic quality when assessed based on the NOS, whereas most of the INTERPHONE-related studies and studies by other groups did not use blinding and were thus categorized as having low methodologic quality". Prasad et al. (2017) investigated the results of 22 case-controlled studies which showed an increased risk of brain tumor with long-term exposure to mobile phone radiation while industry-funded research tended to underestimate the risk.

An analysis of the Interphone study by Morgan (2009) noted eleven design flaws, including1) selection bias, 2) insufficient latency time, 3) definition of 'regular' cellphone user, 4) exclusion of young adults and children, 5) no cosideration for cell phone exposure in rural areas where they would be radiating at higher power levels, 6) exposure to other transmitting sources are excluded, 7) exclusion of brain tumor types, 8) recall accuracy of cellphone use, and 9) funding bias.

In the first court case to award damages to a plaintiff for a brain tumor caused by cell phones, an Italian court excluded cancer-based studies related to cellphones that had been financed by telecommunications companies., according to a news articles (Williams, 2017).

3.2. Current Federal Communications Commission (FCC) radiofrequency guidelines

Physicists and engineers point out that non-ionizing radiofrequency radiation, which we use in modern telecommunications today, has too low an energy unit per photon to move electrons in an atom, causing ionization, as seen with radiation from X-rays and radioactive materials (WHO, 1981). They argue that heat is the only measure of harm which is meaningful with regards to health and safety of RF EMR. Scientists, however, have elucidated other mechanisms whereby cellular functioning can be disrupted by non-thermal exposures to radiofrequency radiation.

Current FCC Guidelines for non-ionizing radiation exposure were developed over two decades ago and are based on heating of tissues over short exposure periods (6 min for occupational/controlled and 30 min for public/uncontrolled exposure) (FCC, 1997, 2015; FCC, 2013). There are no long term exposure guidelines, nor are there guidelines for low level, non-thermal or biological effects considered in the International Commission on Non-Ionizing Radiation Protection (ICNIRP) standards which are the basis for standards used worldwide (ICNIRP, 2009; Hardell, 2017).

With the passage of the federal Telecommunication Act of 1996 responsibility for safety of non-ionizing radiation was passed from the EPA to the FCC (1996). At the time, the EPA was preparing recommendations for long term exposure which were not included in the FCC guidelines (EPA, 1981; EPA, 1992). In a 1993 scientific conference sponsored by the US EPA Office of Air and Radiation and the Office of Research and Development, the EPA discussed its concerns about public RF exposure and the need for additional research. The report noted health issues that remained unsolved including "potential effects of long term, low level exposure; and biophysical mechanisms." (EPA, 1993).

A World Health Organization summary of Environmental Health Criteria from a Warsaw conference in 1973 stated "More data on the relationship between biological and health effects and the frequency and mode of generation of the radiation, particularly in complex modulations, are needed." They further state, "Prevention of potential hazards is a more efficient and economical way of achieving control than belated efforts to reduce existing levels." (WHO, 1981).

Sage and Carpenter, among others, note that for adequate public health protection a biological safety standard is needed that considers current research indicating cellular harm, long term effects of constant exposure and effects on vulnerable populations (Sage and Carpenter,

2012; Blank et al., 2015). FCC recommendations have not been updated to include current literature on cellular affects at levels below FCC guidelines or effects of long term exposure (EPA Letter, 2002). It is notable that Section 704 of the 1996 Telecommunications Act specifies the following: “Section 704(a) of the 1996 Act expressly preempts state and local government regulation of the placement, construction, and modification of personal wireless service facilities on the basis of the environmental effects of radio frequency emissions to the extent that such facilities comply with the FCC's regulations concerning such emissions (FCC, 1996). This policy directly contradicts current evidence of harm.

3.2.1. FCC guidelines and specific absorption rate

In 1985, the FCC adopted thermal guidelines to be used for evaluating human exposure to radiofrequency (RF) emissions, incorporating electric and magnetic field strength and power density limits for Maximum Permissible Exposure (MPE) for transmitters operating at frequencies between 300 kHz and 100 GHz. These were updated in 1996. Limits are defined by either Specific Absorption Rate (SAR) or power density (PD). SAR is a measure of heat absorption in the body expressed in watts per kilogram and is typically used for near field exposure to cell phones and wireless devices. For the general population the SAR limit in the U.S. is 0.08 W/kg as averaged over the whole-body and for localized heating (typically for cell phones) the SAR limit should not exceed 1.6 W/kg as averaged over any 1 g of tissue. These SAR standards apply at operating frequencies between 100 kHz and 6 GHz (ICNIRP, 2009). This guideline gives a heating safety factor of 50 (ICNIRP, 2009; Hardell, 2017).

The closer the device is to the body, the higher the absorption of radiation and heat generated, thus in manufacturers device information inserts, the SAR is usually listed with safety recommendations for limiting close proximity to the body. The recommendation for devices such as tablets and portable laptop computers in FCC documents Page 5 states “For purposes of RF exposure evaluation, a mobile device is defined as a transmitting device designed to be used in other than fixed locations and to be generally used in such a way that a separation distance of at least 20 cm is normally maintained between the transmitter's radiating structures and the body of the user or nearby persons.” (FCC, 1997).

For cell phones, the distance from the head to comply with SAR standards varies between different phones and manufacturers. Usually a minimum separation of millimeters from the head is noted in the manufactures literature. For example, the Samsung model SM-G920A insert states “Body-worn SAR testing has been carried out at a separation distance of 1.5 cm. To meet RF exposure guidelines during body-worn operation, the device should be positioned at least this distance away from the body.” (Samsung SAR) Although implantable medical devices are now shielded from external RF EMR to prevent interference, manufactures may still include safety information. Samsung notes, “A minimum separation of six (6) inches should be maintained between a handheld wireless mobile device and an implantable medical device, such as a pacemaker or implantable cardioverter defibrillator, to avoid potential interference with the device.” (Samsung Guide).

3.2.2. Higher frequency radiation FCC measurement standards: 6–100 Ghz

For higher frequencies energy is measured as power per unit area or power density (PD). Power density is typically expressed in terms of watts per square meter (W/m^2) or milliwatts per square centimeter meter (mW/cm^2). The conversion is 10 W/m = 1 mW/cm^2. It is also expressed as microwatts per square centimeter (μW/cm^2) for lower power measurements (1 mW/cm^2 = 1000 μW/m^2) (SLAC, 2015). Power density limits vary with frequency but at cell phone frequencies of 1500 MHz the FCC limit is 1 mW/cm^2 (or 1000 μW/m^2) in the U.S. (Madjar, 2016). The FCC notes in the OET Bulletin 65, that “devices that operate above 6 GHz (*e.g.,* millimeter-wave devices) localized SAR is not an appropriate means for evaluating exposure. At these higher frequencies, exposure from portable devices should be evaluated in terms of power density MPE limits instead of SAR.” (FCC, 1997).

3.2.3. EMR frequencies

Wireless communication uses electromagnetic frequencies to carry data through the air. Typically, this includes both a carrier wave and an operating wave. Frequency is measured in cycles per second. 1 Hz (Hz) is one cycle per second. A Kilohertz (KHz) is 1000 cycles per second, a Megahertz (MHz) is a million cycles per second and a Gigahertz (GHz) pulses at a billion cycles per second. The typical 2.4 GHz Wi-Fi pulses at 2.4 billion cycles per second. Broadband was introduced in the 2000's as a high capacity transmission technology that allows a wide band of radio frequencies to operate simultaneously. This multiple frequency technology can be delivered with copper wires, fiberoptic, cables or through wireless transmission (Chiou, 2005; Goleniewski, 2001). In order to carry data at faster speeds, each new generation of telecommunications uses higher frequency radio waves. The higher frequencies used for new technology are added to the existing frequencies of older technology (Chávez-Santiago et al., 2015; 5G Vision EU). This creates an increasing mix of electromagnetic frequency exposures.

3.2.4. The electromagnetic spectrum and wireless devices

Radio frequency (RF) comprises a continuum of the electromagnetic spectrum wavelengths below visible and infrared light from about 3 kHz to 300 GHz. The wavelengths in the radio frequency range in size from hundreds of meters to fractions of a a centimeter.

Radio communications operate with long waves that are a meter to many kilometers wide. These are in the 3 Hz to 300 MHz band. AM Radio operates from 540 to 1600 kHz. FM Radio operates from 76 to 108 MHz. Long radio communication wavelengths are also known as groundwaves and can follow the earths contours beyond the horizon an thus transmit far distances.

Microwave radio frequencies are 300 MHz to 300 GHz. Higher frequency and shorter wavelength radio frequencies (microwaves) are now widely used in modern digital communications. First generation (1G) to Fourth generation (4G) radio frequency wavelengths are centimeters to a meter in width and were first used in military communications decades ago. These shorter wavelengths transmit information in a straight line of sight path but for shorter distances. Cell towers thus can transmit dozens of miles away versus typical radio communication towers that can transmit for 100's of miles, depending on the power output, height of the tower, weather and topography. New proposed 5G small cells, with millimeter waves, will transmit only 300 m.

As telecommunication has advanced, the frequencies used have shorter wavelengths and faster data transfer. More data channels can be compressed into the shorter frequency bands enabling more data to be transferred simultaneously. This means more data at faster speeds. Older cell phones and cordless DECT phones use 900 and 1800 MHz wavelengths. Today almost all newer wireless devices use a small range of frequencies clustered near 2.4 GHz, *i.e.* Cell phones, cordless phones, Wi-Fi routers, and Bluetooth. This is the same frequency as microwave ovens but with much less power. To eliminate interference from multiple devices, 5.0 GHz frequencies have been introduced into newer wireless devices. Smart meters operate with both a 900 and 2.4 GHz signals.

Proposed fifth generation (5G) technologies will use frequencies between 30 and 100 GHz which are shorter millimeter wavelengths (1–10 mm) (Nordrum, 2017). This technology is said to carry wireless data 10 times faster than 4G with 1000 times the data.

3.2.5. Generational cell phone frequencies

1G - Analog- Advanced Mobile Phone Service (AMPS) was commercially introduced in the 1980's and operated with voice only at 800 MHz with a continuous wave signal.

2G - Global System for Mobile Communications (GSM) and Code Division Multiple Access (CDMA), are variants of 2G systems,

introduced in 1990's providing text messaging, multimedia messaging and internet access. These were used in the first digital cell phones. Frequencies are a combination of 850 and 1900 or 900 and 1800 MHz.

3G - Universal Mobile Telecommunications Service (UMTS)- Introduced in 1998 with broadband features providing data transfer, mobile internet and video calling. There are dozens of frequency bands available in the 800–900 MHz range and the 1700–2100 MHz range depending on the carrier.

4G - Long Term Evolution (LTE) –Was released in 2008 with higher frequency broadband supporting faster web access, gaming, video conferencing, and HD Mobile TV. These frequencies are in the 700 MHz, 1700/2100 MHz and the 2500–2690 MHz range.

5G- Device-to-Device Communication, Proposed for expansion of the Internet of Things (IoT). Uses wavelengths from 30 to 100 GHz and possibly up to 300 GHz.

3.3. The science of biological harm from non-ionizing radiation

A growing body of scientific literature documents evidence of non-thermal cellular damage from non-ionizing wireless radiation used in telecommunications. This RF EMR has been shown to cause an array of adverse effects on DNA integrity, cellular membranes, gene expression, protein synthesis, neuronal function, the blood brain barrier, melatonin production, sperm damage and immune dysfunction (Dasdag et al., 2015a; Dasdag et al., 2015a, 2015b; La Vignera et al.al., 2012; Levine et al.al., 2017). Human health effects associated with wireless radiation include infertility, neurodegenerative changes and brain cancer (Wyde, 2016; IARC, 2011) (; Sage and Carpenter, 2012; Kim et al., 2017; Kesari et al., 2011; Kesari et al., 2012a, 2012b; Zhang et al., 2016; Agarwal et al., 2011, 2008; Al-Quzwini et al., 2016; Banik, 2003; Consales, 2012; D'Andrea and Chalfin, 2000; Desai et al., 2009: Prasad et al., 2017). In addition, electrosensitivity to wireless and electrical devices is being increasingly recognized by scientists and physicians (Hojo et al., 2016; Singh and Kapoor, 2014; Belpomme et al., 2015). A biologically based standard has been recommended with a scientific benchmark to a "lowest observable effect level" for RF EMR at 0.003 uW/cm^2 (Sage and Carpenter, 2012). There is also growing evidence of harm to trees, wildlife and other biosystems (Sivani and Sudarsanam, 2013).

3.3.1. Oxidation mechanism of cellular harm

A well-studied potential mechanism of harm from radiofrequency radiation is one of cellular oxidation. Healthy biological systems require a balance of oxidation and antioxidation to fight infection and prevent disease (44, 45, 46). A review of the literature by Yakymenko et al. (2016) confirmed that in 93 of 100 studies, non-ionizing radiofrequency radiation caused a cellular stress response with excessive reactive oxygen species. He concluded, "oxidative stress induced by RFR exposure should be recognized as one of the primary mechanisms of the biological activity of this kind of radiation."

Reactive oxygen species (ROS) are a normal part of cellular processes and cell signaling. Overproduction of ROS that is not balanced with either endogenous antioxidants (superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), glutathione (GSH), melatonin), or exogenous antioxidants (Vitamin C, Vitamin E, carotenoids, polyphenols) allows the formation of free radicals that oxidize and damage DNA, proteins, membrane lipids and mitochondria. Mitochondrial DNA is more susceptible to DNA damage than nuclear DNA as it lacks histones, has a reduced ability to repair DNA, and is not protected from mitochondrial reactive oxygen species (Görlach et al., 2015). Excess ROS have been associated with exposure to toxic chemicals, pesticides and metals (Abdollahi et al., 2004; Sharma et al., 2014: Drechsel and Patel, 2008). Oxidative damage from ROS has been increasing linked to the development and/or exacerbation of a number of chronic diseases and cancer (Thannickal and Fanburg, 2000; Valko et al., 2006; Bouayed and BohnBohn, 2010; Görlach et al., 2015; Alfadda and Sallam, 2012).

3.3.2. Electrosensitivity

An increasing number of people are reporting a variety of symptoms with exposure to wireless devices and infrastructure, including headaches, insomnia, dizziness, nausea, lack of concentration, heart palpitations and depression. These are now recognized as signs of electrosensitivity or electromagnetic hypersensitivity. A personal communication and case history was recently described by Dr. Scott Eberle, a hospice physician who, after an inciting event, became electrosensitive, and discovered his continuing physical symptoms were due to wireless radiation from his computer and cell phone. (Eberle, 2014; Eberle, 2014, 2017). Reports of electrosensitivity with these non-specific but sometimes debilitating symptoms have incidences from 1.5% of the population in Sweden to 13.3% of the population in Taiwan (Hedendahl et al., 2015).

The United States Access Board recognizes "that multiple chemical sensitivities and electromagnetic sensitivities may be considered disabilities under the ADA if they so severely impair the neurological, respiratory or other functions of an individual that it substantially limits one or more of the individual's major life activities." (ADA, 2014).

It is notable that these same symptoms were described in military personnel working near radar communications systems. A 1981 NASA report, "Electromagnetic Field Interactions: Observed Effects and Theories", described microwave sickness with a host of symptoms recorded, including headaches, eyestrain, fatigue, dizziness, disturbed sleep at night, sleepiness in daytime, moodiness, irritability, unsociability, hypochondriac reactions, feelings of fear, nervous tension, mental depression, memory impairment, pulling sensation in the scalp and brow, loss of hair, pain in muscles and heart region, breathing difficulties, and increased perspiration of extremities (NASA, 1981).

3.4. 5G technology would be a mix of microwave frequencies

The vision of the next generation of communications technology, 5G, is to have instantaneous delivery of large volumes of multimedia content over a seamless wireless connection anywhere at any time (Chávez-Santiago et al., 2015; Greenemeier, 2015). To do this, new high frequency, faster delivery bands and a wider spectral bandwidth would need to be allocated in the 6–100 GHz range. Because the shorter frequencies transmit across short distances (hundreds of meters), a dense network of cellular antennas would need to be deployed throughout cities and neighborhoods, including extensive battery backup systems.

This system proposes to be additive with a blended architecture. Plans are in the works to adopt underused licensed frequencies throughout the spectrum. It will be a network of networks, with multiple layers of frequencies, multiple devices, and multiple user interactions (Jacobfeuerborn, 2015). Small cell deployments can be used as high capacity Wi-Fi hotspots forming an outdoor mesh network with an intergenerational mix of communications networks with 5G added later. It is not a completely new technology which will be deployed, according to Chavez-Santiago et al. (2015), but a spectrum-usage combination. "5G

3.4.1. 5G deployment by 2020

The start of commercial deployment of 5G systems is expected in 2020 with rapid expansion thereafter" to support more than one thousand times today's mobile traffic volume" (Chávez-Santiago et al., 2015).

The development of this technology has been underway for several years with research and development funding from many sources. Public, private and academic partnerships have been developed to advance this initiative. There is a race for R&D with significant resources invested with expected much higher return on investment. In 2012, the University of Surrey in the United Kingdom secured £35 million in funding for the 5G Innovation Centre, 5GIC, which offers testing facilities to mobile operators developing spectrum technologies. This year

they announced their first 5G digital gaming initiative (University of Surrey, 2017). 5G Americas are planning to boost development of broadband technologies in Latin America as well (FCC Letter, 2016; 5G Americas, 2017).

3.4.2. Are there downsides to 5G telecommunications technology?

Industry papers discussing 5G, talk about markets, business models, and start-ups. New white papers have focused on needs for public safety, emergency response and earthquake preparedness. How much benefit will there really be for adding all this hyper-connecting technology compared to public health and environmental consequences? A more thorough investigation is needed with all the downsides included in the analysis, including E-Waste, global climate change, toxics emissions, occupational safety, privacy, security, public safety from widespread battery backup systems, and most critically, direct human health and environmental risks. We already have 911 and satellite communications for emergencies. If this technology is adopted we will lose our critical copper landline wires that are safer, more secure, and require no battery backups. Regulations regarding cost, access and usage of this widespread internet system have yet to be determined. Health and psychosocial effects are largely absent from business discussions.

3.4.3. More antennas and more frequencies are needed for a seamless connection

5G millimeter waves (MMW) are extremely high-frequency (30–300 GHz) electromagnetic radiation. In general, the longer the wavelength the longer it travels and the farther apart broadcast stations are placed.The 5G short higher frequency millimeter wavelengths travel shorter distances (a few hundred meters) thus to achieve a seamless integrated wireless system the “small cell” antenna are proposed to be placed about every 250 m. The exact frequencies of MMW desired for the next-generation of high-speed wireless technologies are not yet configured but industry letters to the FCC seek to open all the frequencies up to 100 GHz, with some suggesting even higher frequencies (FCC Letter 5G Americas). These MMW frequencies will be mixed with current longer microwave frequencies to achieve integration of systems. At higher power densities, cell tower studies show that symptoms of electrosensitivity occur within about 300 m of a cell tower (Santini et al., 2002; Zothansiama et al., 2017). The added frequencies and close proximity of small cell antenna in this dense network are a valid concern for residents. MMW are absorbed by anything with water such as foliage thus causing attenuation of the signals and making connections with the system line of sight only (Rappaport and Deng, 2015). Millimeter waves also do not penetrate walls. This has been a problem for designers, who are still trying to figure out a solution.

3.4.4. FCC exposure limits for 5G millimeter waves

SAR levels are used for cell phones, tablets and other handheld wireless devices to determine regulatory compliance. For millimeter wavelength devices and infrastructure power density above 6 GHz (FCC) and above 10 GHz (ICNIRP) needs to be measured with power density (FCC, 1997; Wu et al., 2015a) This is due to the higher energy absorption in a shallow area that causes heating more rapidly resulting in much higher SAR levels. The FCC maximum permissible exposure (MPE) in terms of power density for frequencies between 1.5 and 100 GHz is 10 mW/cm^2 over a 30 min period (FCC, 1997; Romanenko et al., 2014). Heat generated is a concern in handheld devices for 5G but is still considered the only valid measure of harm, no biological cellular alterations are considered (Wu et al., 2015a).

3.4.5. Studies on millimeter wavelenghts

Millimeter waves (MMW) are absorbed by water in living plants, bacteria, insects and human skin with variable effects. Because of shallow penetration of MMW, the eyes and skin are of primary concern. Bacterial effects have also been examined with evidence of antibiotic resistance caused by MMW. In humans, the penetration depth of more than 90% of the transmitted power is absorbed in the epidermal and dermal layers (Wu et al., 2015a). Because the depth is so superficial, higher heating occurs more quickly with less dissipation. Many biological responses to MMW irradiation can be initiated within the skin (Isaac et al., 2012; Ziskin, 2013; Gandhi and Riazi, 1986). Systemic signaling in the skin can result in physiological effects on the nervous system, heart, and immune system mediated through neuroendocrine mechanisms (Pakhomov et al., 1998). Currently MMW is used for some high speed wireless networks (Sundeep et al., 2012) and radar sensors for car navigation (Menzel, and Moebius, 2012). Considering planned ubiquitous and continuous MMW exposure there is a need to understand any potentially negative health effects of these frequencies (National Research Council US, 1983; Liu et al., 2014; Drean et al., 2013; Mahamoud et al., 2016; Nelson et al., 2000).

3.4.5.1. Skin effects. Numerous experimental studies have shown that surface effects of low intensity MMW can be quite substantial, inducing a number of biological changes, even at non thermal levels, including cell membrane effects (Feldman et al., 2009; Ramundo-Orlando et al., 2009; Feldman et al., 2008; Millenbaugh et al., 2006; Enin et al., 1992; Ramundo-Orlando, 2012; Ziskin, 2013; Hayut et al., 2014; Ney and Abdulhalim, 2011; Chernyakov et al., 1989). There are MMW studies showing both beneficial and adverse effects, depending on frequency, modulation, power density, polarization, and exposure time (Belyaev et al., 2000). MMW has been used for many years as a non-invasive therapeutic modality in complementary medicine in many Eastern European countries for pain therapy (Taras et al., 2006) with some evidence that short term application of certain frequencies stimulate release of endogenous opioids in the skin (Ziskin, 2013). For a contrary purpose, the military are using 95 GHz MMW for non-lethal active denial systems (Gross, 2010). It appears that the 95 GHz MMW range affects the cutaneous nociceptors and act as a threatening stimulus without heating or thermal damage (LeVine, 2009). The mechanism has not been fully elucidated but researchers have proposed the sweat glands as a target. Feldman et al. (2008; 2009) demonstrated that the sweat ducts in human skin are helically shaped tubes, filled with a conductive aqueous solution. Their research indicates that sweat ducts in the skin could behave as antennas and thus respond to millimeter waves.

3.4.5.2. Ocular effects. There is particular concern for 5G applications as the eyes would also receive significant radiation especially for near field exposures. Cataracts remain the leading cause of blindness in the world, and are a societal burden due to the high incidence, cost and consequences to quality of life (CDC, 2015). NIH statistics from 2010 show there is a 17.11% overall prevalence of cataracts over age 40 (NIH NEH, 2010) and a steady rise in cataract surgeries (Gollogly et al., 2013). An eight-year study showed the total Medicare costs for cataract surgery alone was approximately 3.6 billion, which is 60% of all eye care costs (Ellwein and Urato, 2002). Well established risk factors in the development of cataracts are age, smoking, diabetes, and UVB exposure. Research is pointing towards oxidative damage as a general mechanism for age related cataracts (Spector, 1995; Ye et al., 2001; Abraham et al., 2006). Microwave radiation is also a known cause of cataracts with heat being an undisputed mechanism. The eyes lack sufficient blood flow to dissipate heat effectively. There is some evidence that repeated low level exposures to microwave radiation could cause cataracts but researchers agree that more studies are needed (Vignal et al., 2009; Carpenter and Van Ummeren, 1968; Moss et al., 1977; Foster et al., 1986; Van Umersen and Cogan, 1976; Riva et al., 2005; Ryzhov et al., 1991; Drean et al., 2013; Morgan et al., 2015).

Frey (1985) elucidates the reasons why the earlier Appleton and McCrossan study found no cataractogenesis from microwave exposure after reviewing their data. He found 3 major flaws in the study design and interpretation. These were 1) the exposed group likely included

people with little or no exposure 2) control group consisted of people working with equipment known to cause eye damage 3) they never performed a statistical analysis on their data. Nevertheless, their study was held up as proof there were no harmful effects from radiofrequency radiation. Frey notes the need to critically review negative studies as this contributes to the distortion and distrust of science.

Lipman et al. (1988) noted that microwaves most commonly cause anterior and/or posterior subcapsular lenticular opacities both in experimental animals, epidemiologic studies and case reports. They indicate that cataract formation is related to the power of the microwave radiation and duration of exposure. Lipman concludes that until further definitive research is conducted on the mechanisms of injury and protective measures identified, mechanical shielding is recommended to minimize the possibility of development of radiation-induced cataracts.

Cutz (1989) in his publication "Effects of microwave radiation on the eye: The occupational health perspective", looked at occupational exposure to RF EMR noting that eye effects from microwave radiation can be thermal or non-thermal and that lens opacities can be generated experimentally in animals with relatively high intensity RF EMR (power density above 100 mW/cm^2). He states that for lower intensities cumulative exposures may cause damage. He also reported that microwaves caused degeneration of retinal nerve endings. Long term effects were not determined, pointing to the need for additional research.

Kues and Monhan (1992) at John Hopkins University, researched the effects of low-level microwave radiation on the primate eye using 1.25 and 2.45 GHz wavelengths for 4 h daily for 3 consecutive days. They identified damaging ocular effects including corneal lesions, increased vascular permeability and degeneration of photoreceptors in the retina. They found that pulsed microwave exposure produced abnormalities at lower power densities than continuous wave exposure. These were relatively short exposure periods.

Prost et al. (1994) was one of the first to study the effects of millimeter microwave radiation on the eye. He noted that microwaves of different wavelengths have been implicated in the development of cataracts. His research found that low power millimeter waves produced lens opacity in rats over a 58-day period (10 mW/cm2), indicating MMW is a predisposing factor for cataracts.

Bormusov et al. (2008) examined the non-thermal effects of high frequency radiation from cell phones and other wireless devices on lens epithelium. They found both reversible and irreversible ocular changes and notes that the effects they saw with short term exposure at low levels could translate to similar effects with cataracts over a 10–20 year period of cumulative exposure. They state "It is recommended to use cell phones from a distance to minimize exposure, thus reducing any potential harmful effects of cell phone use on the lens."

Yu and Yao (2010) reviewed literature on microwave radiation and induction of cataracts. Reports of non-thermal biologic effects of microwave radiation include alteration of cell proliferation and apoptosis, inhibition of gap junctional intercellular communication, stress response and genetic instability. They concluded that further *in vivo* studies are needed.

Shawaf (2015) reported on an acute bilateral cataract development in a healthy young radar worker due to accidental high power microwave exposure. He notes "there are also non-thermal effects of microwave energy on the eye including pressure waves and physical stretching, deformation, and tearing of the membranes of the lens cells."

In a 2014 publication in the Institute of Electrical and Electronics Engineers journal, IEEE Transactions on Microwave Theory and Techniques, Sasaki et al. (2014) reported their *in vivo* rabbit experiments for operating frequencies ranging from 24.5 to 95 GHz, measuring temperature elevation. Their studies suggest that corneal damage occurred at an incident power density of 300 mW/cm^2. They conclude that ocular heating should be the basis for safety guidelines for near field exposure. It is mentioned however that only a few experimental studies in the miilimeter wavelengths were used to determine the current exposure guideline limits.

In another IEEE publication looking at MMW health effects, Wu et al. (2015b) support current standards of safety based on heat but point out that the MMW research on biological effects is sparse relative to that of longer microwave frequencies. They advise that additional studies may be needed to examine the potential biological effects of MMW radiation in order to develop appropriate consumer guidelines, especially where antennas are located close to the body.

From the available literature it appears that microwave frequencies including MMW proposed for 5G can have non-thermal biological effects on the lens of the eye. 5G deployment will add shorter wavelengths to longer wavelengths which have not been adequately tested for long term exposure. With the expected rise of wearable ocular digital technology devices such as virtual reality for gaming, entertainment, the social sciences and healthcare, there will be significantly more exposure to microwave radiation very close to the orbit. Current safety guidelines are based on heat measurements. The paucity of current literature on ocular effects of millimeter wavelengths highlights the need for much more independent research and precaution moving forward to prevent an epidemic of ocular pathology.

3.4.5.3. Review of effects. In a very thorough review article, Pakhomov et al. (1998) looked at the biological effects of MMW. He examined dozens of studies and cites research demonstrating profound effects of MMW on all biological systems including cells, bacteria, yeast, animals and humans. Some effects were clearly thermal, however, many of the studies showed non-thermal biological effects at low intensities. Both negative and positive responses were seen depending on frequency, power, resonance and exposure time. Researchers found at times even small difference in frequencies could have very different biological effects.

Pakhomov summarized the studies and included effects on heart rate variability, teratogenicity, and bacterial growth alterations with antibiotic resistance. Chernyakov et al. (1989) induced heart rate changes in anesthetized frogs by microwave irradiation of remote skin areas. Complete denervation of the heart did not prevent the reaction. This suggested a reflex mechanism of the MMW action involving certain peripheral receptors. Potekhina et al. (1992) found certain frequencies from 53 to 78 GHz band continuous wave changed the natural heart rate variability in anesthetized rats. He showed that some frequencies had no effect (61 or 75 GH) while other frequencies (55 and 73 GHz) caused pronounced arrhythmia. There was no change in skin or whole body temperature.

One study of MMW teratogenic effects was performed in Drosophila flies by Belyaev et al. (1990). Embryos were exposed to 3 different GHz frequencies for 4–4.5 h at 0.1 mW/cm^2. He found that irradiation at 46.35 GHz, but not at 46.42 or 46.50 GHz, caused marked effects including an increase in morphological abnormalities and decreased survival. It was felt the MMW disturbed DNA-protein interactions at that particular frequency. Bulgakova et al. (1996) in studies with 14 different antibiotics showed how MMW exposure of the bacterium *S. aureus* affects its sensitivity to antibiotics with different mechanisms of action. The MMW increased or decreased antibiotic sensitivity depending on the antibiotic concentration.

Pakhomov warned that there was a possibility of significant bioeffects of millimeter wave technology at current safety standards and more study was needed. He called for replication of studies especially long term effects of MMW.

Pakhomov concluded that the effects were not necessarily linear as different individuals may react differently, there were unknown and uncontrolled factors affecting sensitivities, and electrosensitivity to millimeters may be real with 30 to 80% of test subjects able to feel low intensity millimeter wave radiation.

3.4.5.4. Immune system. Kolomytseva et al. (2002), looked at the function of peripheral blood neutrophils under whole-body exposure

of healthy mice to low-intensity extremely high-frequency electromagnetic radiation (EHF EMR, 42.0 GHz, 0.15 mW/cm^2, 20 min daily). The study showed 50% suppression of phagocytic activity of neutrophils after a single exposure to MMW radiation with the authors noting a profound effect on nonspecific immunity.

Lushnikov et al. (2003) investigated cell-mediated immunity and nonspecific inflammatory response in mice exposed to low-intensity extremely high-frequency electromagnetic radiation (EHF EMR, 42.0 GHz, 0.1 mW/cm2, 20 min daily). They found that MMW radiation reduced both immune and nonspecific inflammatory responses (130). Other research by the same group corroborated an anti-inflammatory effect of MMW that appeared mediated by the immune neuro-endocrine system. This could explain some of the reported beneficial effects. Long term exposure was not mentioned.

Gapeev et al. (2003) showed for the first time that low-intensity extremely high- frequency MMH electromagnetic radiation *in vivo* causes effects on spatial organization of chromatin in cells of lymphoid organs. Chromatin is a complex of DNA and proteins that forms chromosomes within the nucleus of eukaryotic cells. He exposed mice to a single whole-body exposure for 20 min at 42.0 GHz and 0.15 mW/cm^2. He suggests that the effects were due to involvement of the neuroendocrine and central nervous systems.

3.4.5.5. Tumor suppression. Makar et al. (2005) showed that MMW irradiation at 42.2 GHz can up-regulate natural killer (NK) cell functions with short exposures. An increase in TNF-alpha was also identified. Logani et al. (2006) investigated inhibition of tumor growth transplants with short 30 min pretreatment with MMW. They found a reduction in tumor metastasis by MMWs mediated through activation of NK cells. Long term exposure was not investigated.

3.4.5.6. Gene expression. Chen et al. (2008) found upregulation of some genes in human keratinocytes with MMW exposure at low power density (1.0 mW/cm^2 millimeter).

Habauzit et al. (2014) looked at gene expression in keratinocytes with 60 GHz exposure at the upper limit of current guidelines and concluded, “In our experimental design, the high number of modified genes (665) shows that the ICNIRP current limit is probably too permissive to prevent biological response.”

3.4.5.7. Bacterial antibiotic resistance. Bulgakova et al. (1996) irradiated staphylococcus cultures with different frequencies of MMW with non-thermal intensities with short exposure periods (minutes). He found changes in bacterial sensitivities developed in 5 of 14 antibiotics used in sublethal concentrations with both suppression and stimulation of growth.

Shcheglov et al. (2002) examined MMW on *E. coli* cells at various cell densities and frequencies. His work suggests that cell-to-cell communication may be involved in bacterial responses to weak EMF.

Isakhanian and Trchunian (2005) irradiated water and buffer solution with low intensity MMW and found that the irradiated water had a bactericidal effect that disappeared after repeated exposure and the buffer solution increased growth of bacteria. They concluded this was due to membranotrophic effects. Repeated irradiation reversed the bactericidal effects indicating that a compensatory mechanism was involved.

Torgomyan and Trchounian (2013) reviewed research on the mechanisms of bactericidal and antibiotic resistance after exposure to low intensity MMW. They suggest that alterations in water structure, cell membrane or the genome leading to changes in metabolic pathways could account for these effects. The importance of this research is emphasized in light of ongoing concerns about bacterial resistance to antibiotics.

Soghomonyan et al. (2016) found that MMW affected growth and antibiotic sensitivity of *E. coli* and many other bacteria via non-thermal mechanisms. This may lead to antibiotic resistance.

3.5. Data gaps need to be closed before launching 5G millimeter devices

5G technology with its diverse blend of frequencies and densely packed cell antenna network will substantially increase exposure to electromagnetic radiation. Significant data gaps exist for research into both MMW and mixed frequencies for biological effects, long term exposure and vulnerable populations (children, pregnant women, chronically ill). Considering current peer reviewed science, predictable harm to life forms within the mixed frequency mesh networks with negative consequences appears likely over time. For electrosensitive individuals, it will add to their physical symptoms and isolation, with significant reduction in non-exposed safe havens. There is an urgent need for independent studies to guide development of effective public health standards and policies.

3.6. Technology addiction: overuse and over-connection

Overuse of technology and mental health is another related but no less important issue. Physicians, social scientists and educators are concerned with the over-connection to technology, especially in children and adolescents. Psychiatrists have reported an increase in technology addiction, cyberbullying, depression, insomnia, loss of empathy and impaired social-emotional learning in their young patients. Internet game disorder has been found to have psychological and neural effects similar to other types of impulse control disorders and addictions which are both substance and non-substance-related (Chi et al., 2016; Király et al., 2017; Meng et al., 2015; Sanchez-Carbonell et al., 2008; Tamura,Tamura et al., 2017; Feng et al., 2017) Lack of outdoor play and psychological well-being for young children is also of growing concern (Xu et al., 2016). We should begin to question the supposed benefits versus the true risks of a hyper-connected society.

3.7. What is public health?

There are many definitions of public health but one succinct definition is, “Public health is what we, as a society, do collectively to assure the conditions for people to be healthy.” (Upshur, 2015). Public health involves the science and art of preventing and controlling disease, promoting health, monitoring populations for health assessments, identifying causes, identifying effective interventions and assuring equity in populations and communities (APHA, 2017; CDCCDC, 2017).

Public health involves an ever widening range of topics. John R. Goldsmith, MD, MPH, a pioneer in public health, wrote a seminal article in 1997 called “From Sanitation to Cellphones: Participants and Principles Involved in Environmental Health Protection” (Goldsmith, 1997a, 1997b). This work details the history of public health over his decades working in this field. He describes four phases of public health issues: sanitation (prior to 1914), industrialization (1915–1950), emissions constraints (1951–1995) and then globalization (1996 on). He notes three common principles of public health which apply through all those phases, 1) The need for regulation by government 2) Need for a market by which protection of environmental health is economically attractive compared to alternatives and 3) Social acceptability, with cultural norms endorsing protective versus risk generating behavior.

3.7.1. Wireless technologies: a question of public health

A growing number of scientists have articulated the need to recognize that the increase in wireless technologies is a serious emerging and neglected public health threat. (Blank et al., 2015; Goldsmith, 1997a, 1997b; Sage and Carpenter, 2012). In a recent poll, public health scientists were asked what they consider to be emerging public health issues (Bernier, 2017). Responses included issues such as racism, bullying, gun violence, gang violence, adult obesity and climate change. They were also asked what defines a public health issue. The open forum identified the following criteria.

1. The health impacts are preventable and modifiable.
2. There is a high prevalence of a risk factor.
3. There is an increase in incidence and prevalence.
4. There is an economic impact.
5. There is disability, morbidity and mortality.
6. It can affect a large population.
7. A collaborative effort is needed to solve it.
8. The problem can be recognized unencumbered by lack of funding, cultural norms, or politics.

For wireless technology to be considered a public health issue in this regard there would need to be broad recognition and consensus that wireless technology could cause or contribute to diseases such as brain cancer, neurodegeneration, developmental defects, infertility, electrosensitivity and addiction. The cost and burden could then be calculated. Wireless technology could fulfill the other criteria in that there is an unprecedented high prevalence in the use of wireless devices, it can affect the population as a whole, and will require collaborative action to solve. The biggest obstacles appear to be of a cultural, economic and political nature along with a noted lack of funding in the U.S. for independent scientific research on health effects of RF EMR that is free of industry influence or bias. As with tobacco, the science was denied and doubt created until overwhelming research and evidence of harm decades later shifted the debate and protective regulations followed. Chemical companies followed tobacco with similar methods to dismiss and manipulate science that was not in their favor (Michaels, 2008).

4. Conclusion

Although 5G technology may have many unimagined uses and benefits, it is also increasingly clear that significant negative consequences to human health and ecosystems could occur if it is widely adopted. Current radiofrequncy radiation wavelengths we are exposed to appear to act as a toxin to biological systems. A moratorium on the deployment of 5G is warranted, along with development of independent health and environmental advisory boards that include independent scientists who research biological effects and exposure levels of radiofrequency radiation. Sound regulatory policy regarding current and future telecommunications initiative will require more careful assessment of risks to human health, environmental health, public safety, privacy, security and social consequences. Public health regulations need to be updated to match appropriate independent science with the adoption of biologically based exposure standards prior to further deployment of 4G or 5G technology.

Considering the current science, lack of relevant exposure standards based on known biological effects and data gaps in research, we need to reduce our exposure to RF EMR where ever technically feasible. Laws or policies which restrict the full integrity of science and the scientific community with regards to health and environmental effects of wireless technologies or other toxic exposures should be changed to enable unbiased, objective and precautionary science to drive necessary public policies and regulation. Climate change, fracking, toxic emissions and microwave radiation from wireless devices all have something in common with smoking. There is much denial and confusion about health and environmental risks, along with industry insistence for absolute proof before regulatory action occurs (Frentzel-Beyme, 1994; MichaelsMichaels, 2008). There are many lessons we have not learned with the introduction of novel substances, which later became precarious environmental pollutants by not heeding warning signs from scientists (Gee, 2009). The threats of these common pollutants continue to weigh heavily on the health and wellbeing of our nation. We now accept them as the price of progress. If we do not take precautions but wait for unquestioned proof of harm will it be too late at that point for some or all of us?

Acknowledgements

I wish to thank David Smernoff, Ph.D. and Joel Moskowitz, Ph.D. for their help with editing and proof reading this article.

References

5G Americas, 2017. All Latin American Countries Fail to Reach ITU Spectrum Recommendations. (21 June 2017). 〈http://www.5gamericas.org/en/newsroom/press-releases/all-latin-american-countries-fail-reach-itu-spectrum-recommendations/〉.
5G Vision. 5G infrastructure Association. 〈https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf〉.
Abdollahi, M., Ranjbar, A., Shadnia, S., Nikfar, S., Rezaie, A., 2004. Pesticides and oxidative stress: a review. Sci. Monit. 10 (6), RA141–RA147. 〈https://www.ncbi.nlm.nih.gov/pubmed/15173684〉.
Abraham, A.G., Condon, N.G., Gower, E.W., 2006. The new epidemiology of cataract. Ophthalmol. Clin. North Am. 19, 415–425. 〈https://www.researchgate.net/publication/6728154_The_New_Epidemiology_of_Cataract#pf9〉.
ADA, 2014. Americans with Disability. United States Access Board. IEQ Indoor Environmental Quality Project. https://www.access-board.gov/research/completed-research/indoor-environmental-quality/introduction.
Adams, J.A., Galloway, T.S., Mondal, D., Esteves, S.C., Mathews, F., 2014. Effect of mobile telephones on sperm quality: a systematic review and meta-analysis. Environ. Int. 70, 106–112. 〈http://www.ncbi.nlm.nih.gov/pubmed/24927498〉.
Agarwal, A., Deepinder, F., Sharma, R.K., Ranga, G., Li, J., 2008. Effect of cell phone usage on semen analysis in men attending infertility clinic: an observational study. Fertil. Steril. 2008 (Jan), 89. 〈http://www.ncbi.nlm.nih.gov/pubmed/17482179-〉.
Agarwal, A., Singh, A., Hamada, A., Kesari, K., 2011. Cell phones and male infertility: a review of recent innovations in technology and consequences. Int. Braz. J. Urol. 37 (4), 432–454. 〈http://www.ncbi.nlm.nih.gov/pubmed/21888695〉.
Alfadda, Assim A., Sallam, Reem M., 2012. Review article: reactive oxygen species in health and disease. J. Biomed. Biotechnol. 2012 (2012). http://dx.doi.org/10.1155/2012/936486. 〈https://www.hindawi.com/journals/bmri/2012/936486/〉.
Al-Quzwini, O.F., Al-Taee, H.A., Al-Shaikh, S.F., 2016. Male fertility and its association with occupational and mobile phone towers hazards: an analytic study. Middle East Fertil. Soc. J. 21 (4), 236–240. 〈http://www.sciencedirect.com/science/article/pii/S1110569016300127〉.
American Public Health Association, 2017. What is Public Health? 〈https://www.apha.org/what-is-public-health〉.
Banik, S., 2003. Bioeffects of microwave—a brief review. Bioresour. Technol. 87, 155–159. 〈https://www.researchgate.net/profile/Dr_Shyamal_Banik/publication/10745209_Bioeffects_of_microwave_-A_brief_review/links/543f95d80cf27832ae8b8e41.pdf〉.
Belpomme, D., Campagnac, C., Irigaray, P., 2015. Reliable disease biomarkers characterizing and identifying electrohypersensitivity and multiple chemical sensitivity as two etiopathogenic aspects of a unique pathological disorder. Rev. Environ. Health 30 (4), 251–271. http://dx.doi.org/10.1515/reveh-2015-0027. 〈https://www.ncbi.nlm.nih.gov/pubmed/26613326〉.
Belyaev, I.Y., Shcheglov, V.S., Alipov, E.D., Ushakov, V.D., 2000. Nonthermal effects of extremely high-frequency microwaves on chromatin conformation in cells in vitro—dependence on physical, physiological, and genetic factors. IEEE Trans. Microw. Theory Tech. 48 (11), 2172–2179. 〈https://www.researchgate.net/publication/299296102_Nonthermal_effects_of_extremely_high-frequency_microwaves_on_chromatin_conformation_in_cells_in_vitro_-_Dependence_on_physical_physiological_and_genetic_factors〉.
Belyaev, I.Ya, Okladnova, O.V., Izmailov, D.M., Sheglov, V.S., Obukhova, L.K., 1990. Differential sensitivity of developmental stages to low-level electromagnetic radiation of extremely ultrahigh frequency. Dokl. Akad. Nauk SSSR [Ser. B Geol. Chim. Biol.] 12, 68–70 (in Russian).
Belyaev, Igor, 2005. Non-thermal biological effects of microwaves. Microw. Rev. 11, 13–29. 〈http://www.tandfonline.com/doi/abs/10.1080/15368370500381844?journalCode=iebm20〉.
Bernier, R.H., 2017. What constitutes a public health problem? Epimonitor (Accessed Sept 30, 2017). 〈http://epimonitor.net/List_of_Public_Health_Issues.htm〉.
Birks, L., Guxens, M., Papadopoulou, E., Alexander, J., Ballester, F., et al., 2017. Maternal cell phone use during pregnancy and child behavior problems in five birth cohorts. International Society for environmental epidemiology. Environ. Health Perspect. http://dx.doi.org/10.1016/j.envint.2017.03.024. 〈https://www.ncbi.nlm.nih.gov/pubmed/28392066〉.
Blank, M., Havas, M., Kelly, E., Lai, H., Moskowitz, J., 2015. International appeal: scientists call for protection from non-ionizing electromagnetic field exposure. Eur. J. Oncol. 20 (3–4). 〈http://mattioli1885journals.com/index.php/Europeanjournalofoncology/article/view/4971〉.
Bormusov, E., Andley, U.P., Sharon, N., Schächter, L., Lahav, A., et al., 2008. Non-thermal electromagnetic radiation damage to lens epithelium. Open Ophthalmol. J. 2, 102–106. 〈https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2694600/〉.
Bortkiewicz, A., Gadzicka, E., Szymczak, W., 2017. Mobile phone use and risk of intracranial tumors and salivary gland tumors – a meta-analysis. Int. J. Occup. Med. Environ. Health 30 (1), 27–43. http://dx.doi.org/10.13075/ijomeh.1896.00802. (21). 〈https://www.ncbi.nlm.nih.gov/pubmed/28220905〉.
Bouayed, Jaouad, Bohn, Torsten, 2010. Exogenous antioxidants—double-edged swords in cellular redox state. Oxid. Med. Cell Longev. 3 (4), 228–237. http://dx.doi.org/10.4161/oxim.3.4.12858.. 〈https://www.ncbi.nlm.nih.gov/pmc/articles/

PMC2952083/〉.
Bulgakova, V.G., Grushina, V.A., Orlova, T.I., Petrykina, Z.M., Polin, A.N., Noks, P.P., Kononenko, A.A., Rubin, A.B., 1996. Effect of millimeter-band radiation of non-thermal intensity on the sensitivity of staphylococcus to various antibiotics. Biofizika 41, 1289–1293. (in Russian). 〈https://www.ncbi.nlm.nih.gov/pubmed/9044624〉.
Carlberg, M., Hardell, L., 2017. Evaluation of mobile phone and cordless phone use and glioma risk using the Bradford Hill viewpoints from 1965 on association or causation. Biomed. Res. Int. 2017 (2017), 9218486. http://dx.doi.org/10.1155/2017/9218486. 〈https://www.ncbi.nlm.nih.gov/pubmed/28401165〉.
Carpenter, R.L., Van Ummersen, C.A., 1968. The action of microwave radiation on the eye. J. Microw. Power 3 (1), 3–19. http://dx.doi.org/10.1080/00222739.1968.11688664. 〈http://www.tandfonline.com/doi/abs/10.1080/00222739.1968.11688664〉.
CDC 2017. Chronic Disease Prevention and Health Promotion. CDC. June 2017. 〈https://www.cdc.gov/chronicdisease/overview/index.htm〉.
CDC. Vision Health Initiative. 2015. 〈https://www.cdc.gov/visionhealth/basics/ced/index.html〉.
Chávez-Santiago, R., Szydełko, M., Kliks, A., Foukalas, F., Haddad, Y., Nolan, K.E., Kelly, M.Y., Moshe, M.T., Balasingham, I., 2015. 5G: the convergence of wireless communications. Wirel. Personal. Commun. 83, 1617–1642. http://dx.doi.org/10.1007/s11277-015-2467-2. 〈https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4821549/〉.
Chen, Q., Lu, D.Q., Jiang, H., Xu, Z.P., 2008. Effects of millimeter wave on gene expression in human keratinocytes. Zhejiang Da Xue Xue Bao Yi Xue Ban. 37 (1), 23–28. 〈https://www.ncbi.nlm.nih.gov/pubmed/18275115〉.
Chernyakov, G.M., Korochkin, V.L., Babenko, A.P., Bigdai, E.V., 1989. Reactions of biological systems of various complexity to the action of low- level EHF radiation. In: Devyatkov, N.D. (Ed.), Millimeter Waves in Medicine and Biology. Radioelectronica, Moscow, pp. 141–167 (in Russian).
Chi, X., Lin, L., Zhang, P., 2016. Internet addiction among college students in china:china: prevalence and psychosocial correlates. Cyber. Behav. Soc. Netw. 19 (9), 567–573. http://dx.doi.org/10.1089/cyber.2016.0234. 〈https://www.ncbi.nlm.nih.gov/pubmed/27635444〉.
Chiou, I.Y., 2005. Next generation broadband communications. IEEE Xplore. 〈http://ieeexplore.ieee.org/document/1553748/〉.
Consales, C., 2012. Electromagnetic fields, oxidative stress, and neurodegeneration. Int. J. Cell Biol. 2012 (2012). http://dx.doi.org/10.1155/2012/683897.
Cutz, A., 1989. Effects of microwave radiation on the eye: the occupational health perspective. Lens Eye Toxic. Res. 6 (1–2), 379–386. 〈http://europepmc.org/abstract/med/2488031〉.
D'Andrea, J.A., Chalfin, S., 2000. Effects of microwave and millimeter wave radiation on the eye. In: Klauenberg, B.J., Miklavčič, D. (Eds.), Radio Frequency Radiation Dosimetry and Its Relationship to the Biological Effects of Electromagnetic Fields. NATO Science Series (Series 3: High Technology) 82 Springer, Dordrecht. http://dx.doi.org/10.1007/978-94-011-.
Dasdag, S., Akdag, M.Z., Erdal, M.E., Erdal, N., Ay, O.I., Ay, M.E., Yilmaz, S.G., Tasdelen, B., Yegin, K., 2015a. Effects of 2.4 GHz radiofrequency radiation emitted from Wi-Fi equipment on microRNA expression in brain tissue. Int. J. Radiat. Biol. 91 (7), 555–561. http://dx.doi.org/10.3109/09553002.2015.1028599.
Dasdag, S., Akdag, M.Z., Erdal, M.E., Erdal, N., Ay, O.I., Ay, M.E., Yilmaz, S.G., Tasdelen, B., Yegin, K., 2015b. Long term and excessive use of 900 MHz radiofrequency radiation alter microRNA expression in brain. Int. J. Radiat. Biol. 91 (4), 306–311. http://dx.doi.org/10.3109/09553002.2015.997896.
Desai, N.R., Kavindra, K., Kesari, K.K., Agarwal, A., 2009. Pathophysiology of cell phone radiation: oxidative stress and carcinogenesis with focus on the male reproductive system. Reprod. Biol. Endocrinol. 7, 114. http://dx.doi.org/10.1186/1477-7827-7-114. 〈https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2776019/〉.
Dréan, Y.L., Mahamoud, Y.S., Page, Y.L., Habauzit, D., Le Quément, C., Zhadobov, M., Ronan Sauleau, R., 2013. State of knowledge on biological effects at 40–60 GHz. Comptes Rendus Phys. 14 (5), 402–411. http://dx.doi.org/10.1016/j.crhy.2013.02.005. 〈http://www.sciencedirect.com/science/article/pii/S1631070513000480〉.
Drechsel, D.A., Patel, M., 2008. Role of reactive oxygen species in the neurotoxicity of environmental agents implicated in Parkinson's disease. Free Radic. Biol. Med. 44, 1873–1886. http://dx.doi.org/10.1016/j.freeradbiomed.2008.02.008. 〈https://www.ncbi.nlm.nih.gov/pubmed/18342017〉.
Eberle, S., 2014. What's the diagnosis, doctor? Sonoma Med. Fall 2014, 27–32. 〈http://www.nbcms.org/about-us/sonoma-county-medical-association/magazine/fall-2014-medicine-and-politics-departments-personal-history-whats-the-diagnosis-doctor.aspx?pageid=719&tabid=747〉.
Eberle, S., 2017. An underworld journey: learning to cope with electromagnetic hypersensitivity. Ecopsychology 9 (2), 106–111. http://dx.doi.org/10.1089/eco.2016.0036. 〈http://online.liebertpub.com/doi/abs/10.1089/eco.2016.0036?journalCode=eco〉.
Ellwein, L.B., Urato MA, C.J., 2002. Use of eye care and associated charges among the medicare population. 1991–1998. Arch. Ophthalmol. 120 (6), 804–811. http://dx.doi.org/10.1001/archopht.120.6.804. 〈http://jamanetwork.com/journals/jamaophthalmology/fullarticle/271126〉.
Enin, L.D., Akoev, G.N., Potekhina, I.L., Oleĭner, V.D., 1992. Effect of extremely high-frequency electromagnetic radiation on the function of skin sensory endings. Patol. Fiziol. Eksp. Ter. (5–6), 23–25. 〈https://www.ncbi.nlm.nih.gov/pubmed/?term=1302819〉.
EPA Letter, 2002. U.S. Environmental Protection Agency letter describing clarification of adequacy of Federal Communications Commission (FCC) radio frequency guidelines for non-thermal and long term health effects. 〈http://www.humboldtgov.org/DocumentCenter/View/2858〉.
EPA, 1981. Index of Publications on Biologic Effects of Electromagnetic Radiation (0–100 GHz) 1981. Lists 3627 Studies to 1980. 〈https://nepis.epa.gov/Exe/ZyNET.exe/9101FEXP.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1981+Thru+1985&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Dat%5C81thru85%5CTxt%5C00000024%5C9101FEXP.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL〉.
EPA, 1992. Electric and Magnetic Fields: An EPA perspective on research needs and priorities for improving health risk assessment. 〈https://nepis.epa.gov/Exe/ZyNET.exe/30001ZN7.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1991+Thru+1994&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Dat%5C91thru94%5CTxt%5C00000001%5C30001ZN7.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL〉.
EPA, 1993. US EPA Office of Air and Radiation and Office of Research and Development: Summary of Results of the April 26–27, 1993. Radiofrequency Radiation conference. Anaylsis of Panel Discussions. Volume 1. March 1995. 〈https://nepis.epa.gov/Exe/ZyNET.exe/9100O6Z4.txt?ZyActionD=ZyDocument&Client=EPA&Index=1995%20Thru%201999&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&UseQField=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5CZYFILES%5CINDEX%20Dat%5C95THRU99%5CTXT%5C00000028%5C9100O6Z4.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=11〉.
Esmekaya, M.A., Ozer, C., Seyhan, N., 2011. 900 MHz pulse-modulated radiofrequency radiation induces oxidative stress on heart, lung, testis and liver tissues. Gen. Physiol. Biophys. 30 (1), 84–89. http://dx.doi.org/10.4149/gpb_2011_01_84. 〈https://www.ncbi.nlm.nih.gov/pubmed/21460416〉.
FCC, 1997. Current guidelines – evaluating compliance with FCC Guidelines for human exposure to radiofrequency electromagnetic fields. OET Bull (65 Edition 97-01. August 1997). 〈http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.159.3824&rep=rep1&type=pdf〉.
FCC Letter 5G Americas, 2016. FCC Filing 14-177 5G Americas. Posted 10/3/16. 〈https://www.fcc.gov/ecfs/filing/1093077796003/document/1093077796003462f〉.
FCC, 1996. Telecommunications Act of 1996. 〈https://www.fcc.gov/general/telecommunications-act-1996〉.
FCC, 2013. Radio Frequency Safety. 〈https://www.fcc.gov/general/radio-frequency-safety-0〉.
FCC, 2015. RF Safety FAQ. Updated November 25, 2015. 〈https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#Q24〉.
Feldman, Y., Puzenko, A., Ben Ishai, P., Caduff, A., Agranat, A.J., 2008. Human skin as arrays of helical antennas in the millimeter and submillimeter wave range. Phys. Rev. Lett. 100 (12), 128102. http://dx.doi.org/10.1103/PhysRevLett.100.128102. 〈https://www.ncbi.nlm.nih.gov/pubmed/18517913〉.
Feldman, Y., Puzenko, A., Ben Ishai, P., Caduff, A., Davidovich, I., Sakran, F., Agranat, A.J., 2009. The electromagnetic response of human skin in the millimetre and submillimetre wave range. Phys. Med. Biol. 54 (11), 3341–3363. http://dx.doi.org/10.1088/0031-9155/54/11/005. 〈https://www.ncbi.nlm.nih.gov/pubmed/19430110〉.
Feng, W., Ramo, D.E., Chan, S.R., James, A., Bourgeois, J.A., 2017. Internet gaming disorder: trends in prevalence 1998–2016. Addict. Behav. 75, 17–24. http://dx.doi.org/10.1016/j.addbeh.2017.06.010. 〈http://www.sciencedirect.com/science/article/pii/S0306460317302320〉.
Foster, M.R., Ferri, E.S., Hagan, G.J., 1986. Dosimetric study of microwave cataractogenesis. Bioelectromagnetics 7 (2), 129–140. 〈https://www.ncbi.nlm.nih.gov/pubmed/3741488〉.
Frentzel-Beyme, R., 1994. John R. Goldsmith on the usefulness of epidemiological data to identify links between point sources of radiation and disease. Public Health Rev. 22 (3–4), 305–320. 〈https://www.ncbi.nlm.nih.gov/pubmed/7708942〉.
Frey, A.H., 1985. Data analysis reveals significant microwave-induced eye damage in humans. J. Microw. Power Electromagn. Energy 20 (1), 53–55. 〈https://www.ncbi.nlm.nih.gov/pubmed/3847507〉.
Gandhi, O.P., Riazi, A., 1986. Absorption of millimeter waves by human beings and its biological implications. IEEE Trans. Microw. Theory Tech. MTT 34 (2), 228–235. 〈http://ieeexplore.ieee.org/document/1133316/〉.
Gapeev, A.B., Lushnikov, K.V., Shumilina, Iu.V., Sirota, N.P., Sadovnikov, V.B., Chemeris, N.K., 2003. Effects of low-intensity extremely high frequency electromagnetic radiation on chromatin structure of lymphoid cells in vivo and in vitro. Radiats Biol. Radioecol. (1), 87–92. 〈https://www.ncbi.nlm.nih.gov/pubmed/12677665〉.
Gee, D., 2009. Late lessons from early warnings: towards realism and precaution with EMF? Pathophysiology 16 (2–3), 217–231. http://dx.doi.org/10.1016/j.pathophys.2009.01.004. 〈https://www.ncbi.nlm.nih.gov/labs/articles/19467848/〉.
Goldsmith, J.R., 1997. Epidemiologic evidence relevant to radar(microwave)effects.

Environ. Health Perspect. 105 (Suppl 6), 1579–1587. ⟨http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1469943/⟩.
Goldsmith, J.R., 1997. From sanitation to cell phones: participants and principles involved in environmental health protection. Public Health Rev. 25, 123–149.
Goleniewski, L., 2001. Telecommunications Technology Fundamentals. Telecommunications Essentials: The Complete Global Source for Communications Fundamentals, Data Networking and the Internet, and Next-Generation Networks. Informit. ⟨http://www.informit.com/articles/article.aspx?P = 24687&seqNum = 4⟩.
Gollogly, H.E., Hodge MS, D.O., St. Sauver, J.L., Erie, J.C., 2013. Increasing incidence of cataract surgery: population-based study. J. Cataract Refract. Surg. 39 (9), 1383–1389. http://dx.doi.org/10.1016/j.jcrs.2013.03.027. ⟨https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4539250/⟩.
Görlach, A., Dimova, E.Y., Petry, A., Martínez-Ruiz, A., Hernansanz-Agustín, P., Rolo, A.P., et al., 2015. Reactive oxygen species, nutrition, hypoxia and diseases: problems solved? Redox Biol. 6, 372–385. http://dx.doi.org/10.1016/j.redox.2015.08.016. ⟨https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4565025/⟩.
Greenemeier, L., 2015. Will millimeter waves maximize 5G Wireless? Sci. Am. ⟨https://www.scientificamerican.com/article/will-millimeter-waves-maximize-5g-wireless/⟩.
Grigoriev, Y.G., Mikhailov, V.F., Ivanov, A.A., Maltsev, V.N., Ulanova, A.M., StavrakovaI, N.M., Nikolaeva, A., Grigoriev, O.A., 2010. Autoimmune processes after long-term low-level exposure to electromagnetic fields part 4. oxidative intracellular stress response to the long-term rat exposure to nonthermal RF EMF. Biophysics 55, 1054–1058. ⟨https://link.springer.com/article/10.1134/S0006350910060308⟩.
Gross, M.L., 2010. Medicalized weapons & modern war. Hastings Cent. Rep. 40 (1), 34–43. ⟨https://www.ncbi.nlm.nih.gov/pubmed/?term = 20166514⟩.
Habauzit, D., Quément, C.L., Zhadobov, M., Martin, C., Aubry, M., Sauleau, R., Dréan, Y.L., 2014. Transcriptome analysis reveals the contribution of thermal and the specific effects in cellular response to millimeter wave exposure. PLoS One. http://dx.doi.org/10.1371/journal.pone.0109435. ⟨http://journals.plos.org/plosone/article?id = 10.1371/journal.pone.0109435⟩.
Hardell, L., Carlberg, M., Söderqvist, F., Mild, K.H., 2013a. Pooled analysis of case-control studies on acoustic neuroma diagnosed 1997–2003 and 2007–2009 and use of mobile and cordless phones. Int. J. Oncol. 43 (4), 1036–1044. http://dx.doi.org/10.3892/ijo.2013.2025. ⟨https://www.ncbi.nlm.nih.gov/pubmed/?term = 23877578⟩.
Hardell, L., Carlberg, M., Söderqvist, F., Mild, K.H., 2013b. Case-control study of the association between malignant brain tumours diagnosed between 2007 and 2009 and mobile and cordless phone use. Int. J. Oncol. 43 (6), 1833–1845. http://dx.doi.org/10.3892/ijo.2013.2111. ⟨https://www.ncbi.nlm.nih.gov/pubmed/24064953⟩.
Hardell, Lennart, 2017. World health organization, radiofrequency radiation and health – a hard nut to crack (review). Int. J. Oncol (Published online 21 June 21 2017). ⟨https://www.spandidos-publications.com/10.3892/ijo.2017.4046⟩.
Hassanshahi, A., Shafeie, S.A., Fatemi, I., Hassanshahi, E., Allahtavakoli, M., Shabani, M., Roohbakhsh, A., Shamsizadeh, A., 2017. The effect of Wi-Fi electromagnetic waves in unimodal and multimodal object recognition tasks in male rats. Neurol. Sci. 38 (6), 1069–1076. http://dx.doi.org/10.1007/s10072-017-2920-y. ⟨https://www.ncbi.nlm.nih.gov/pubmed/28332042⟩.
Hayut, I., Ben Ishai, P., Agranat, A.J., Feldman, Y., 2014. Circular polarization induced by the three-dimensional chiral structure of human sweat ducts. Phys. Rev. E Stat. Nonlin. Soft Matter Phys. 89 (4), 042715. http://dx.doi.org/10.1103/PhysRevE.89.042715. ⟨https://www.ncbi.nlm.nih.gov/pubmed/24827286⟩.
Hedendahl, L., Carlberg, M., Hardell, L., 2015. Electromagnetic hypersensitivity – an increasing challenge to the medical profession. Rev. Environ. Health 30 (4), 209–215. http://dx.doi.org/10.1515/reveh-2015-0012. (1). ⟨http://www.ncbi.nlm.nih.gov/pubmed/26372109⟩.
Hojo, S., Tokiya, M., Mizuki, M., Miyata, M., Kanatani, K.T., 2016. Development and evaluation of an electromagnetic hypersensitivity questionnaire for Japanese people. Bioelectromagnetics 37 (6), 353–372. http://dx.doi.org/10.1002/bem.21987. ⟨https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5094565/⟩.
Huss, A., Egger, M., Hug, K., Huwiler-Müntener, K., Röösli, M., 2007. Source of funding and results of studies of health effects of mobile phone use: systematic review of experimental studies. Environ. Health Perspect. 115 (1), 14. ⟨https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1797826/⟩.
IARC, 2017. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Update June 28, 2017. ⟨http://monographs.iarc.fr/ENG/Classification/⟩.
ICNIRP, 2009. International Commission on Non-Ionizing Radiation Protection: icnirp statement on the 'Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)'. Health Phys. 97, 257–258. ⟨https://www.ncbi.nlm.nih.gov/pubmed/19667809⟩.
International Agency for Research on Cancer, 2011. IARC Classifies Radiofrequency Electromagnetic Fields as Possibly Carcinogenic to Humans. ⟨http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf⟩.
Isaac, M., Chiu,1,2,3 Christian, A., von Hehn,1,2,3, Woolf, Clifford J., 2012. Neurogenic inflammation – the peripheral nervous system's role in host defense and immunopathology. Nat. Neurosci. 15 (8), 1063–1067. http://dx.doi.org/10.1038/nn.3144. ⟨https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3520068/⟩.
Isakhanian, V., Trchunian, A., 2005. [Indirect and repeated electromagnetic irradiation of extremely high frequency of bacteria Escherichia coli]. Biofizika 50 (4), 689–692. ⟨https://www.ncbi.nlm.nih.gov/pubmed/16212062⟩.
Jacobfeuerborn, B., 2015. NGMN Alliance White Paper. 2015. A Deliverable by the NGMN Alliance. ⟨https://www.ngmn.org/uploads/media/NGMN_5G_White_Paper_V1_0.pdf⟩.
Kesari, K.K., Kumar, S., Behari, J., 2011. 900-MHz microwave radiation promotes oxidation in rat brain. Electromagn. Biol. Med. 30 (4), 219–234. ⟨https://www.ncbi.nlm.nih.gov/pubmed/22047460⟩.
Kesari, K.K., Kumar, S., Behari, J., 2012a. Pathophysiology of microwave radiation: effect on rat brain. Appl. Biochem. Biotechnol. 166 (2), 379–388. ⟨https://www.ncbi.nlm.nih.gov/pubmed/22134878⟩.
Kesari, K.K., Kumar, S., Behari, J., 2012b. Pathophysiology of microwave radiation: effect on rat brain. Appl. Biochem. Biotechnol. 166 (2), 379–388. http://dx.doi.org/10.1007/s12010-011-9433-6. ⟨https://www.ncbi.nlm.nih.gov/pubmed/22134878⟩.
Kim, J.H., Yu, D.H., Huh, Y.H., Lee, E.H., Kim, H.G., Kim, H.R., 2017. Long-term exposure to 835 MHz RF-EMF induces hyperactivity, autophagy and demyelination in the cortical neurons of mice. Sci. Rep. 20 (7), 41129. http://dx.doi.org/10.1038/srep41129. ⟨https://www.nature.com/articles/srep41129⟩.
Király, O., Griffiths, M.D., King, D.L., Lee, H.K., Lee, S.Y., Bányai, F., Zsila, Á., Takacs, Z.K., Demetrovics, Z., 2017. Policy responses to problematic video game use: a systematic review of current measures and future possibilities. J. Behav. Addict. 1, 1–15. http://dx.doi.org/10.1556/2006.6.2017.050. ⟨https://www.ncbi.nlm.nih.gov/pubmed/28859487⟩.
Kolomytseva, M.P., Gapeev, A.B., Sadovnikov, V.B., Chemeris, N.K., 2002. Suppression of nonspecific resistance of the body under the effect of extremely high frequency electromagnetic radiation of low intensity. Biofizika 47 (1), 71–77. ⟨https://www.ncbi.nlm.nih.gov/pubmed/11855293⟩.
Kues, H.A., Monhan, J.C., 1992. Microwave-induced changes to the primate eye. Johns. Hopkins APL Tech. Dig. 13 (1) (1992, PDF Needed). ⟨http://www.jhuapl.edu/techdigest/views/pdfs/V13_N1_1992/V13_N1_1992_Kues.pdf⟩.
La Vignera, S., Condorelli, R.A., Vicari, E., D'Agata, R., Calogero, A.E., 2012. Effects of the exposure to mobile phones on male reproduction: a review of the literature. J. Androl. 33 (3), 350–356. ⟨http://www.ncbi.nlm.nih.gov/pubmed/21799142⟩.
LeVine, S., 2009. The Active Denial System: A Revolutionary, Non-lethal Weapon for Today's Battlefield. Center for Technology and National Security Policy National Defense University. National Defense University Press. ⟨http://ndupress.ndu.edu/Media/News/Article/1229000/dtp-065-the-active-denial-system-a-revolutionary-non-lethal-weapon-for-todays-b/⟩.
Levine, H., Jørgensen, N., Martino-Andrade, A., Mendiola, J., Weksler-Derri, D., Mindlis, I., Pinotti, R., Swan, S.H., 2017. Temporal trends in sperm count: a systematic review and meta-regression analysis. 25 July 2017. ⟨https://academic.oup.com/humupd/article/doi/10.1093/humupd/dmx022/4035689/Temporal-trends-in-sperm-count-a-systematic-review⟩.
Levitt, B., Lai, H., 2010. Environmental Reviews. 18, 369–395. http://www.nrcresearchpress.com/doi/abs/10.1139/A10-018#citart1.
Lipman, R.M., Tripathi, B.J., Tripathi, R.C., 1988. Cataracts induced by microwave and ionizing radiation. Ophthalmol 33 (3), 200–210. ⟨https://www.ncbi.nlm.nih.gov/pubmed/3068822⟩.
Liu, K., Li, Y., Zhang, G., Liu, J., Cao, J., Ao, L., Zhang, S., 2014. Association between mobile phone use and semen quality: a systemic review and meta-analysis. Andrology 2 (4), 491–501. ⟨https://www.ncbi.nlm.nih.gov/pubmed/24700791⟩.
Logani, M.K., Szabo, I., Makar, V., Bhanushali, A., Alekseev, S., Ziskin, M.C., 2006. Effect of millimeter wave irradiation on tumor metastasis. Bioelectromagnetics 27 (4), 258–264. http://dx.doi.org/10.1002/bem.20208. ⟨https://www.ncbi.nlm.nih.gov/pubmed/16437545⟩.
Lushnikov, K.V., Gapeedv, A.V., Shumilina, Iu.V., Shibaev, N.V., Sadovnikov, V.B., Chmeris, N.K., 2003. Decrease in the intensity of the cellular immune response and nonspecific inflammation upon exposure to extremely high frequency electromagnetic radiation. Biofizika 48 (5), 918–925. ⟨https://www.ncbi.nlm.nih.gov/pubmed/14582420⟩.
Madjar, H.M., 2016. Human radio frequency exposure limits: An update of reference levels in Europe, USA, Canada, China, Japan and Korea. Sept 2016. In: Proceedings of Electromagnetic Compatibility - EMC EUROPE, 2016 International Symposium. IEEE. http://ieeexplore.ieee.org/document/7739164/?Reload = true or ⟨https://www.researchgate.net/publication/303055416_Human_Radio_Frequency_Exposure_Limits_an_update_of_reference_levels_in_Europe_USA_Canada_China_Japan_and_Korea⟩.
Mahamoud, Y.S., Aite, M., Martin, C., Zhadobov, M., Sauleau, R., Le Dréan, Y., Habauzit, D., 2016. Additive effects of millimeter waves and 2-deoxyglucose co-exposure on the human keratinocyte transcriptome. PLoS. One 11 (8). http://dx.doi.org/10.1371/journal.pone.0160810. ⟨https://www.ncbi.nlm.nih.gov/pubmed/27529420⟩.
Makar, V.R., Logani, M.K., Bhanushali, A., Kataoka, M., Ziskin, M.C., 2005. Effect of millimeter waves on natural killer cell activation. Bioelectromagnetics 26 (1), 10–19. http://dx.doi.org/10.1002/bem.20046. ⟨https://www.ncbi.nlm.nih.gov/pubmed/15605409⟩.
Meng, Y., Deng, W., Wang, H., Guo, W., Li, T., 2015. The prefrontal dysfunction in individuals with Internet gaming disorder: a meta-analysis of functional magnetic resonance imaging studies. Addict. Biol. 20 (4), 799–808. http://dx.doi.org/10.1111/adb.12154. ⟨https://www.ncbi.nlm.nih.gov/pubmed/24889021⟩.
Menzel, W., Moebius, A., 2012. Antenna concepts for millimeter-wave automotive radar sensors. Proc. IEEE 100 (7). ⟨http://ieeexplore.ieee.org/document/6165323/⟩.
Michaels, David, 2008. Doubt is Their Product. How Industries Assault on Science Threatens Your Health. Oxford University Press.
Millenbaugh, N.J., Kiel, J.L., Ryan, K.L., Blystone, R.V., Kalns, J.E., Brott, B.J., Cerna, C.Z., Lawrence, W.S., Soza, L.L., Mason, P.A., 2006. Comparison of blood pressure and thermal responses in rats exposed to millimeter wave energy or environmental heat. Shock 25 (6), 625–632. http://dx.doi.org/10.1097/01.shk.0000209550.11087.fd. ⟨https://www.ncbi.nlm.nih.gov/pubmed/16721271⟩.
Morgan, L.L., 2009. Estimating the risk of brain tumors from cellphone use: published case- control studies. Pathophysiology 16 (2–3), 137–147. ⟨http://www.ncbi.nlm.nih.gov/pubmed/19356911⟩.
Morgan, L.L., Kesari, S., Davis, D.L., 2014. Why children absorb more microwave radiation than adults: the consequences. J. Microsc. Ultrastruct. 2 (4), 197–204. http://dx.doi.org/10.1016/j.jmau.2014.06.005. ⟨http://www.sciencedirect.com/science/article/pii/S2213879X14000583⟩.
Morgan, L.L., Miller, A.B., Sasco, A., Davis, D.L., 2015. Mobile phone radiation causes brain tumors and should be classified as aprobable human carcinogen. Int. J. Oncol.

JA 06377

46 (5), 1865–1871. http://dx.doi.org/10.3892/ijo.2015.2908. 〈https://www.ncbi.nlm.nih.gov/pubmed/25738972〉.
Moss, C.E., 1997. Report of electromagnetic radiation surveys of video display terminals. NIOSH. CDC. 〈https://www.cdc.gov/niosh/nioshtic-2/00081009.html〉.
Myung, S.K., Ju, W., McDonnell, D.D., Lee, Y.J., Kazinets, G., Cheng, C.T., Moskowitz, J.M., 2009. Mobile phone use and risk of tumors: a meta-analysis (2009) mobile phone use and risk of tumors: a meta-analysis. J. Clin. Oncol. 20 (33), 5565–5572. (Nov 20, 2009.)(Published online first Oct 13, 2009.). 〈http://ascopubs.org/doi/full/10.1200/jco.2008.21.6366〉.
NASA Report - Electromagnetic Field Interactions with the Human Body: Observed Effects and Theories. April 1981. Jeremy Raines, PhD. 〈https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19810017132.pdf〉.
National Research Council (US) Panel, 1983. Video Displays, Work, and Vision. National Research Council (US) Panel on Impact of Video Viewing on Vision of Workers; National Research Council (US) Committee on Vision. National Academy of Press. 〈https://www.ncbi.nlm.nih.gov/books/NBK216487/〉.
Nelson, D.A., Nelson, M.T., Walters, T.J., Mason, P.A., 2000. Skin heating effects of millimeter- wave irradiation-thermal modeling results. IEEE Trans. Microw. Theory Tech. 48, 2111–2120. 〈http://ieeexplore.ieee.org/document/884202/〉.
Ney, M., Abdulhalim, I., 2011. Modeling of reflectometric and ellipsometric spectra from the skin in the terahertz and submillimeter waves region. J. Biomed. Opt. 16 (6), 067006. http://dx.doi.org/10.1117/1.3592779. 〈https://www.ncbi.nlm.nih.gov/pubmed/21721827〉.
NIH NEH, 2010. National Eye Institute. National Institutes of Health. Prevalence of Cataracts 2010. 〈https://nei.nih.gov/eyedata/cataract/tables〉.
Nordrum, A., 2017. Everything you need to know About 5G. IEEEE. 〈https://spectrum.ieee.org/video/telecom/wireless/everything-you-need-to-know-about-5g〉.
Othman, H., Ammari, M., Sakly, M., Abdelmelek, H., 2017a. Effects of prenatal exposure to WIFI signal (2.45GHz) on postnatal development and and behavior in rat: influence of maternal restraint. Behav. Brain Res. 326, 291–302. http://dx.doi.org/10.1016/j.bbr.2017.03.011. 〈https://www.ncbi.nlm.nih.gov/pubmed/28288806〉.
Othman, H., Ammari, M., Rtibi, K., Bensaid, N., Sakly, M., Abdelmelek, H., 2017b. Postnatal development and behavior effects of in-utero exposure of rats to radiofrequency waves emitted from conventional WiFi devices. Environ. Toxicol. Pharmacol. 52, 239–247. http://dx.doi.org/10.1016/j.etap.2017.04.016. 〈https://www.ncbi.nlm.nih.gov/pubmed/28458069〉.
Pakhomov, A.G., Akyel, Y., Pakhomova, O.N., Stuck, B.E., Michael, R., Murphy, M.R., 1998. Current state and implications of research on biological effects of millimeter waves: a review of the literature. Bioelectromagnetics 19, 393–413. 〈https://www.ncbi.nlm.nih.gov/pubmed/9771583〉.
Potekhina, I.L., Akoyev, G.N., Yenin, L.D., Oleyner, V.D., 1992. Effects of low-intensity electromagnetic radiation in the millimeter range on the cardio-vascular system of the white rat. Fiziol. Zh. [Former. Fiziol. Zh. SSSR] 78, 35–41. (in Russian). 〈https://www.ncbi.nlm.nih.gov/pubmed/1330714〉.
Prasad, M., Kathuria, P., Nair, P., Kumar, A., Prasad, K., 2017. Mobile phone use and risk of brain tumours: a systematic review of association between study quality, source of funding, and research outcomes. Neurol. Sci. 38 (5), 797–810. 〈https://www.ncbi.nlm.nih.gov/pubmed/28213724〉.
Prost, M., Olchowik, G., Hautz, W., Gaweda, R., 1994. Experimental studies on the influence of millimeter radiation on light transmission through the lens. Klin Oczna 96 (8–9), 257–259. 〈https://www.ncbi.nlm.nih.gov/pubmed/7897988〉.
Ramundo-Orlando, A., Longo, G., Cappelli, M., Girasole, M., Tarricone, L., Beneduci, A., Massa, R., 2009. The response of giant phospholipid vesicles to millimeter waves radiation. Biochim. Biophys. Acta (BBA) - Biomembr. 1788 (7), 1497–1507. http://dx.doi.org/10.1016/j.bbamem.2009.04.006. 〈http://www.sciencedirect.com/science/article/pii/S0005273609001175〉.
Ramundo-Orlando, A., Beneduci, A., 2012. Microwave induced shift of the main phase transition in phosphatidylcholine membranes.
Rappaport, Theodore S., Deng, Sijia, 2015. 73 GHz Wideband Millimeter-Wave Foliage and Ground Reflection Measurements and Models. In: IEEE International Conference on Communications (ICC), ICC Workshops, 8–12 June 2015. NYU WIRELESS. 〈http://ieeexplore.ieee.org/document/7247347/versions〉.
Riva, C.E., Logean, E., Falsini, B., 2005. Visually evoked hemodynamical response and assessment of neurovascular coupling in the optic nerve and retina. Riva CE Prog. Retin Eye Res 24 (2), 183–215. http://dx.doi.org/10.1016/j.preteyeres.2004.07.002. 〈https://www.ncbi.nlm.nih.gov/pubmed/15610973〉.
Romanenko, S., Siegel, P.H., Wagenaar, D.A., Pikov, V., 2014. Effects of millimeter wave irradiation and equivalent thermal heating on the activity of individual neurons in the leech ganglion. J. Neurophysiol. 112 (10), 2423–2431. http://dx.doi.org/10.1152/jn.00357.2014. 〈https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4233276/〉.
Ryzhov, A.I., Logvinov, S.V., 1991. Early ultrastructural reactions in various parts of the visual analyzer in guinea pigs after thermogenic microwave irradiation. Arkh Anat. Gistol. Embriol 100 (7–8), 30–36. 〈https://www.ncbi.nlm.nih.gov/pubmed/1843431〉.
Sage, C., Carpenter D.O., 2012. BioInitiative Working Group, BioInitiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Radiation at 〈www.bioinitiative.org〉 (31 December 2012).
Samsung Guide. Samsung Common Phone Health and Safety and Warranty Guide 〈http://www.samsung.com/us/Legal/PHONE-HS_GUIDE_English.pdf〉.
Samsung SAR INFORMATION. 〈http://www.samsung.com/sar/sarMain?Site_cd=&prd_mdl_name=SM-G920A&selNatCd=US&languageCode=EN〉.
Sanchez-Carbonell, X., Beranuy, M., Castellana, M., Chamarro, A., Oberst, U., 2008. Internet and cell phone addiction: passing fad or disorder? Adicciones 20 (2), 149–159. 〈https://www.ncbi.nlm.nih.gov/pubmed/18551228〉.
Santini, R., Santini, P., Danze, J.M., Le Ruz, P., Seigne, M., 2002. Investigation on the health of people living near mobile telephone relay stations: I/incidence according to distance and sex. Pathol. Biol. 50 (6), 369–373. 〈http://www.ncbi.nlm.nih.gov/pubmed/12168254〉.
Sasaki, K., Sakai, T., Nagaoka, T., 2014. Dosimetry using a localized exposure system in the millimeter-wave band for in vivo studies on ocular effects. IEEE Trans. Microw. Theory Tech. 62 (7). http://dx.doi.org/10.1109/TMTT.2014.2323011. 〈http://ieeexplore.ieee.org/document/6818422/〉.
Sharma, B., Singh, S., Siddiqi, N.J., 2014. Review article: biomedical implications of heavy metals induced imbalances in redox systems. BioMed. Res. Int. 2014 (2014). http://dx.doi.org/10.1155/2014/640754. 〈https://www.hindawi.com/journals/bmri/2014/640754/〉.
Shawaf, S., 2015. Rapidly progressing cataract after microwave exposure. Shucri Shawaf. MOJS 2 (1), 00007. http://dx.doi.org/10.15406/mojs.2015.02.00007. 〈http://medcraveonline.com/MOJS/MOJS-02-00007.php〉.
Shcheglov, V.S., Alipov, E.D., Belyaev, I.Y., 2002. Cell-to-cell communication in response of E. coli cells at different phases of growth to low-intensity microwaves. Shcheg. Biochim. Biophys. Acta 1572 (1), 101–106. 〈https://www.ncbi.nlm.nih.gov/pubmed/12204338〉.
Singh, S., Kapoor, N., 2014. Health implications of electromagnetic fields, mechanisms of action, and research needs. Adv. Biol. 2014 (2014), 24. http://dx.doi.org/10.1155/2014/198609. 〈https://www.hindawi.com/archive/2014/198609/〉.
Sivani, S., Sudarsanam, D., 2013. Impacts of radio-frequency electromagnetic field (RF-EMF) from cell phone towers and wireless devices on biosystem and ecosystem—a review. Biol. Med. 4 (4), 202–2016. 〈https://www.researchgate.net/publication/258521207_Impacts_of_radio-frequency_electromagnetic_field_RF-EMF_from_cell_phone_towers_and_wireless_devices_on_biosystem_and_ecosystem-A_review〉.
Soghomonyan, D., Trchounian, K., Trchounian, A., 2016. Millimeter waves or extremely high frequency electromagnetic fields in the environment: what are their effects on bacteria? Appl. Microbiol. Biotechnol. 100 (11), 4761–4771. http://dx.doi.org/10.1007/s00253-016-7538-0. 〈http://www.ncbi.nlm.nih.gov/pubmed/27087527?dopt=Abstract〉.
Spector, A., 1995. Oxidative stress-induced cataract: mechanism of action. FASEB J. 9, 1173–1182. 〈http://www.fasebj.org/content/9/12/1173.short〉.
Stanford Linear Accelerator Laboratory, 2015. Selected Radio Frequency Exposure Limits. Chapter 50: Non-ionizing Radiation (June 30). 〈http://www-group.slac.stanford.edu/esh/eshmanual/references/nirReqExpLimits.pdf〉.
Sundeep, R., Rappaport, T.S., Erkip, E., 2012. Millimeter-wave cellular Wireless networks: potentials and challenges. Proc. IEEE 102 (3). 〈http://ieeexplore.ieee.org/document/6732923/〉.
Tamura, H., Nishida, T., Tsuji, A., Sakakibara, H., 2017. Association between excessive use of mobile phone and insomnia and depression among Japanese adolescents. Int. J. Environ. Res. Public Health 14 (7). http://dx.doi.org/10.3390/ijerph14070701. (29). 〈https://www.ncbi.nlm.nih.gov/pubmed/28661428〉.
Thannickal, V.J., Fanburg, B.L., 2000. Reactive oxygen species in cell signaling. Am. J. Physiol. Lung Cell Mol. Physiol. 279 (6), L1005–L1028. 〈https://www.ncbi.nlm.nih.gov/pubmed/11076791〉.
Torgomyan, H., Trchounian, A., 2013. Bactericidal effects of low-intensity extremely high frequency electromagnetic field: an overview with phenomenon, mechanisms, targets and consequences. Crit. Rev. Microbiol. 39 (1), 102–111. http://dx.doi.org/10.3109/1040841X.2012.691461. 〈https://www.ncbi.nlm.nih.gov/pubmed/22667685〉.
University of Surrey. 5G Innovation Centre. (Accessed 29 Sept 2017). 〈https://www.surrey.ac.uk/5gic〉.
Upshur, R., 2015. What makes a problem a public health issue? The case for palliative care. Slide presentation. Pallium Can. Symp. 〈http://pallium.ca/wp-content/uploads/2015/11/What-Makes-a-Problem-a-Public-Health-Issue-The-Case-for-Palliative-Care-Dr.-Ross-Upshur.-Ross-Upshur.pdf〉.
Valko, M., Rhodes, C.J., Moncol, J., Izakovic, M., Mazur, M., 2006. Free radicals, metals and antioxidants in oxidative stress-induced cancer. Chem. Biol. Interact. 160 (1), 1–40. http://dx.doi.org/10.1016/j.cbi.2005.12.009. (10). 〈https://www.ncbi.nlm.nih.gov/pubmed/16430879〉.
Van Ummersen, C.A., Cogan, F.C., 1976. Effects of microwave radiation on the lens epithelium in the rabbit eye. Arch. Ophthalmol. 94 (5), 828–834. http://dx.doi.org/10.1001/archopht.1976.03910030410012. 〈http://jamanetwork.com/journals/jamaophthalmology/article-abstract/631798?appId=scweb〉.
Vignal, R., Crouzier, D., Dabouis, V., Debouzy, J.C., 2009. Effects of mobile phones and radar radiofrequencies on the eye. Pathol. Biol. 57 (6), 503–508. http://dx.doi.org/10.1016/j.patbio.2008.09.003. 〈https://www.ncbi.nlm.nih.gov/pubmed/19036534〉.
Weng, C.B., Qian, R.B., Fu, X.M., Lin, B., Ji, X.B., Niu, C.S., Wang, Y.H., 2012. A voxel-based morphometric analysis of brain gray matter in online game addicts. 92 (45), 3221–3223. 〈https://www.ncbi.nlm.nih.gov/pubmed/23328472〉.
Williams, J., 2017. Cancer Linked to Cellphone Use, Italian Court Rules in Landmark Case. Newsweek(April 21).
WHO, 1981. Environmental Health Criteria: Radiofrequency and Microwaves. In: Biologic Effects and Health Hazards of Microwave Radiation: Proceedings on International Symposium 1973. Warsaw, Oct 15–18, 1973. Sponsored by the WHO, US Department of Health, Education and Welfare, and The Scientific Council to the Minister of health and Social Welfare, Poland. 〈http://apps.who.int/iris/bitstream/10665/39107/1/9241540761_eng.pdf〉.
Wu, T., Rappaport, T.S., Collins, C.M., 2015b. Safe for generations to come. IEEE Microw. Mag. 16 (2), 65–84. http://dx.doi.org/10.1109/MMM.2014.2377587. 〈https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4629874/〉.
Wu, T., Rappaport, T.S., Collins, C.M., 2015a. The Human Body and Millimeter-Wave Wireless Communication Systems: Interactions and Implications. In: Proceedings of the 2015 IEEE International Conference on Communications (ICC), NYU WIRELESS (accepted in). 〈https://arxiv.org/pdf/1503.05944.pdf〉.

Wyde, Michael, 2016. NTP Toxicology and Carcinogenicity Studies of Cell Phone Radiofrequency Radiation-Slide Presentation. National Toxicology Program. National Institute of Environmental Health Sciences, BioEM2016 Meeting, Ghent, Belgium. 〈https://ntp.niehs.nih.gov/ntp/research/areas/cellphone/slides_bioem_wyde.pdf〉.
Xu, H., Wen, L.M., Hardy, L.L., Rissel, C., 2016. A 5-year longitudinal analysis of modifiable predictors for outdoor play and screen-time of 2- to 5-year-olds. Int. J. Behav. Nutr. Phys. Act. 13 (1), 96. http://dx.doi.org/10.1186/s12966-016-0422-6. 〈https://www.ncbi.nlm.nih.gov/pubmed/27561357〉.
Yakymenko, I., Tsybulin, O., Sidorik, E., Henshel, D., Kyrylenko, O., Kyrylenko, S., 2016. Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation. Electromagn. Biol. Med. 35 (2), 186–202. http://dx.doi.org/10.3109/15368378.2015.1043557. 〈https://www.ncbi.nlm.nih.gov/pubmed/26151230〉.
Ye, J., Yao, K., Lu, D., Wu, R., Jiang, H., 2001. Low power density microwave radiation induced early changes in rabbit lens epithelial cells. Chin. Med. J. 114 (12), 1290–1294. 〈https://www.ncbi.nlm.nih.gov/pubmed/11793856〉.
Yu, Y., Yao, K., 2010. Non-thermal cellular effects of low power microwave radiation on the lens and lens epithelial cells. J. Int. Med. Res. 38 (3), 729–736. http://dx.doi.org/10.1177/147323001003800301. 〈https://www.ncbi.nlm.nih.gov/pubmed/20819410〉.
Zhang, X., Huang, W.J., Chen, W.W., 2016. Microwaves and Alzheimer's disease. Exp. Ther. Med. 12 (4), 1969–1972. http://dx.doi.org/10.1097/00019052-200112000-00008.
Ziskin, M.C., 2013. Millimeter waves: acoustic and electromagnetic. Bioelectromagnetics 34 (1), 3–14. http://dx.doi.org/10.1002/bem.21750. 〈https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3522782/〉.
Zothansiama, Zosangzuali, M., Lalramdinpuii, M., Jagetia, G.C., 2017. Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations. Electromagn. Biol. Med. 36 (3), 295–305. http://dx.doi.org/10.1080/15368378.2017.1350584.. 〈https://www.ncbi.nlm.nih.gov/pubmed/28777669〉.

5G; We Have No Reason to Believe 5G is Safe,
Dr. Joel Moskowitz PhD., Scientific American; 2019

SCIENTIFIC AMERICAN.

We Have No Reason to Believe 5G is Safe

The technology is coming, but contrary to what some people say, there could be health risks

By Joel M. Moskowitz on October 17, 2019

-  Getty Images

The telecommunications industry and their experts have accused many scientists who have researched the effects of cell phone radiation of "fear mongering" over the advent of wireless technology's 5G. Since much of our research is publicly-funded, we believe it is our ethical responsibility to inform the public about what the peer-reviewed scientific literature tells us about the health risks from wireless radiation.

The chairman of the Federal Communications Commission (FCC) recently announced through a press release that the commission will soon reaffirm the radio frequency radiation (RFR) exposure limits that the FCC adopted in the late 1990s. These limits are based upon a behavioral change in rats exposed to microwave radiation and were designed to protect us from short-term heating risks due to RFR exposure.

Yet, since the FCC adopted these limits based largely on research from the 1980s, the preponderance of peer-reviewed research, more than 500 studies, have found harmful biologic or health effects from exposure to RFR at intensities too low to cause significant heating.

Citing this large body of research, more than 240 scientists who have published peer-reviewed research on the biologic and health effects of nonionizing electromagnetic fields (EMF) signed the

International EMF Scientist Appeal, which calls for stronger exposure limits. The appeal makes the following assertions:

"Numerous recent scientific publications have shown that EMF affects living organisms at levels well below most international and national guidelines. Effects include increased cancer risk, cellular stress, increase in harmful free radicals, genetic damages, structural and functional changes of the reproductive system, learning and memory deficits, neurological disorders, and negative impacts on general well-being in humans. Damage goes well beyond the human race, as there is growing evidence of harmful effects to both plant and animal life."

The scientists who signed this appeal arguably constitute the majority of experts on the effects of nonionizing radiation. They have published more than 2,000 papers and letters on EMF in professional journals.

The FCC's RFR exposure limits regulate the intensity of exposure, taking into account the frequency of the carrier waves, but ignore the signaling properties of the RFR. Along with the patterning and duration of exposures, certain characteristics of the signal (e.g., pulsing, polarization) increase the biologic and health impacts of the exposure. New exposure limits are needed which account for these differential effects. Moreover, these limits should be based on a biological effect, not a change in a laboratory rat's behavior.

The World Health Organization's International Agency for Research on Cancer (IARC) classified RFR as "possibly carcinogenic to humans" in 2011. Last year, a $30 million study conducted by the U.S. National Toxicology Program (NTP) found "clear evidence" that two years of exposure to cell phone RFR increased cancer in male rats and damaged DNA in rats and mice of both sexes. The Ramazzini Institute in Italy replicated the key finding of the NTP using a different carrier frequency and much weaker exposure to cell phone radiation over the life of the rats.

Based upon the research published since 2011, including human and animal studies and mechanistic data, the IARC has recently prioritized RFR to be reviewed again in the next five years. Since many EMF scientists believe we now have sufficient evidence to consider RFR as either a probable or known human carcinogen, the IARC will likely upgrade the carcinogenic potential of RFR in the near future.

Nonetheless, without conducting a formal risk assessment or a systematic review of the research on RFR health effects, the FDA recently reaffirmed the FCC's 1996 exposure limits in a letter to the FCC, stating that the agency had "concluded that no changes to the current standards are warranted at this time," and that "NTP's experimental findings should not be applied to human cell phone usage." The letter stated that "the available scientific evidence to date does not support adverse health effects in humans due to exposures at or under the current limits."

The latest cellular technology, 5G, will employ millimeter waves for the first time in addition to microwaves that have been in use for older cellular technologies, 2G through 4G. Given limited reach, 5G will require cell antennas every 100 to 200 meters, exposing many people to millimeter wave radiation. 5G also employs new technologies (e.g., active antennas capable of beam-forming; phased arrays; massive inputs and outputs, known as MIMO) which pose unique challenges for measuring exposures.

Millimeter waves are mostly absorbed within a few millimeters of human skin and in the surface layers of the cornea. Short-term exposure can have adverse physiological effects in the peripheral nervous system, the immune system and the cardiovascular system. The research suggests that long-term exposure may pose health risks to the skin (e.g., melanoma), the eyes (e.g., ocular melanoma) and the testes (e.g., sterility).

Since 5G is a new technology, there is no research on health effects, so we are “flying blind” to quote a U.S. senator. However, we have considerable evidence about the harmful effects of 2G and 3G. Little is known about the effects of exposure to 4G, a 10-year-old technology, because governments have been remiss in funding this research. Meanwhile, we are seeing increases in certain types of head and neck tumors in tumor registries, which may be at least partially attributable to the proliferation of cell phone radiation. These increases are consistent with results from case-control studies of tumor risk in heavy cell phone users.

5G will not replace 4G; it will accompany 4G for the near future and possibly over the long term. If there are synergistic effects from simultaneous exposures to multiple types of RFR, our overall risk of harm from RFR may increase substantially. Cancer is not the only risk as there is considerable evidence that RFR causes neurological disorders and reproductive harm, likely due to oxidative stress.

As a society, should we invest hundreds of billions of dollars deploying 5G, a cellular technology that requires the installation of 800,000 or more new cell antenna sites in the U.S. close to where we live, work and play?

Instead, we should support the recommendations of the 250 scientists and medical doctors who signed the 5G Appeal that calls for an immediate moratorium on the deployment of 5G and demand that our government fund the research needed to adopt biologically based exposure limits that protect our health and safety.

ABOUT THE AUTHOR(S)

Joel M. Moskowitz

Joel M. Moskowitz, PhD, is director of the Center for Family and Community Health in the School of Public Health at the University of California, Berkeley. He has been translating and disseminating the research on wireless radiation health effects since 2009 after he and his colleagues published a review paper that found long-term cell phone users were at greater risk of brain tumors. His Electromagnetic Radiation Safety website has had more than two million page views since 2013. He is an unpaid advisor to the International EMF Scientist Appeal and Physicians for Safe Technology.

https://blogs.scientificamerican.com/observations/we-have-no-reason-to-believe-5g-is-safe/

5G-Millimeter Waves; Nonthermal Effects of Extremely High-Frequency Microwaves on Chromatin Conformation in Cells in vitro—Dependence on Physical, Physiological, and Genetic Factors. IEEExPlore. (Belyaev et al); 2000

Nonthermal Effects of Extremely High-Frequency Microwaves on Chromatin Conformation in Cells *in vitro*—Dependence on Physical, Physiological, and Genetic Factors

Igor Y. Belyaev, Victor S. Shcheglov, Eugene D. Alipov, and Vadim D. Ushakov

***Abstract*—There is a substantial number of studies showing biological effects of microwaves of extremely high-frequency range [i.e., millimeter waves (MMWs)] at nonthermal intensities, but poor reproducibility was reported in few replication studies. One possible explanation could be the dependence of the MMW effects on some parameters, which were not controlled in replications. We studied MMW effects on chromatin conformation in *Escherichia coli* (*E. coli*) cells and rat thymocytes. Strong dependence of MMW effects on frequency and polarization was observed at nonthermal power densities. Several other factors were important, such as the genotype of a strain under study, growth stage of the bacterial cultures, and time between exposure to microwaves and recording of the effect. MMW effects were dependent on cell density during exposure. This finding suggested an interaction of microwaves with cell-to-cell communication. Such dependence on several genetic, physiological, and physical variables might be a reason why, in some studies, the authors failed to reproduce the original data of others.**

***Index Terms*—Biological applications of electromagnetic radiation, biomedical effects of electromagnetic radiation, genetics, polarization.**

I. Introduction

MICROWAVES in the frequency range of 30–300 GHz are often called millimeter waves (MMWs) because the wavelength in vacuum belongs to the interval of 1–10 mm. The biological effects of MMWs have been studied for over 20 years starting with investigations of Webb [1], Vilenskaya *et al.* [2], Devyatkov [3], and Gründler *et al.* [4]–[9]. Several reviews were devoted to the effects of MMWs [7], [10]–[14]. The most recent review summarized more than 100 MMW investigations in biology and medicine and indicated several problems in this field of research [14]. One of them is the question about so-called nonthermal effects.

Due to the efficient absorption of MMWs in water solutions and biological tissues, significant variations in specific absorption rate (SAR) is observed through an irradiated sample. Khizhnyak and Ziskin [15] found specific microoscillations of temperature in irradiated water solutions. Such phenomena were supposed to explain at least some bioeffects of MMWs. MMW irradiation of thin layers results in significant heating at power density (PD) above 1 mW/cm^2. MMW bioeffects at this and higher levels are usually attributed to induced heating. Nevertheless, the observed MMW effects were not always explained by heating, even at the thermal levels of exposure [16].

The well-known example for nonthermal effects of MMWs is the study of Gründler *et al.* [4]–[9]. For over ten years, this group consistently reported the resonance effects of MMWs on the growth of yeast cells. Different exposure systems and analytical facilities were used, leading to the same conclusions about resonance response of yeast cells to nonthermal MMWs. Sophisticated system for image processing recognition was used, which allowed a very precise analysis of the cell cycle in individual cells. The effects were observed at PD of 10^{-12} W/cm^2 and could not be explained by heating [9].

Despite of a variety of reported MMW bioeffects, only a few independent replications were performed [17]–[19]. The apparent conclusion of these replications is that the original data on MMW effects are poorly reproduced in independent experiments.

Significant effects of nonthermal MMWs on the chromatin conformational state (CCS) in *Escherichia coli* (*E. coli*) cells and thymocytes of rats have been observed by our group [20]–[30]. MMW effects on CCS were dependent on several physical, physiological, and genetic parameters. The data suggested that a number of variables should be controlled in original experiments and in replication studies. In this paper, we describe the dependence of MMW effects on all these parameters based mainly on the data obtained by our group and in comparison with the recently published data of others.

II. AVTD Technique

The main body of results analyzed in this paper was obtained with the method of anomalous viscosity time dependence (AVTD). This technique is based on the radial migration of high molecular weight DNA–protein complexes such as nucleoids in rotary viscometer [31]. The physical model of AVTD was developed by Kryuchkov *et al.* [32] based on the theory

Manuscript received November 10, 1999; revised May 3, 2000. This work was supported by the Swedish Council for Work Life Research and by the Swedish Radiation Protection Institute.

I. Y. Belyaev is with the Department of Molecular Genome Research, Stockholm University, S-106 91 Stockholm, Sweden and also with the Department of Radiation Physics, Biophysics and Ecology, Moscow Engineering Physics Institute, Moscow 115409, Russia.

V. S. Shcheglov, E. D. Alipov, and V. D. Ushakov are with the Department of Radiation Physics, Biophysics and Ecology, Moscow Engineering Physics Institute, Moscow 115409, Russia.

Publisher Item Identifier S 0018-9480(00)09714-3.

0018–9480/00$10.00 © 2000 IEEE

of radial migration [33]–[35]. The changes in AVTD were observed in *E. coli* cells of several strains and rat thymocytes after exposure to microwaves *in vitro* [20]–[30]. The AVTD changes have been also observed upon treatment of cells with DNA/chromatin-specific chemicals such as ethidium bromide (EtBr) and etoposide VP-16 [28], [36], [37]. Several experimental observations have suggested that an increase in AVTD in response to MMWs is caused by relaxation of DNA domains and, consequently, decrease in AVTD is caused by chromatin condensation. Single-cell gel electrophoresis confirmed this suggestion [38].

III. Frequency and Power Dependencies of MMW Effects

Effects of low-intensity microwaves on repair of radiation-induced DNA breaks were studied by the AVTD method in *E. coli* K12 AB1157 [20]. Significant suppression of repair was found when X-irradiated cells were exposed to microwaves within frequency ranges of 51.62–51.84 and 41.25–41.50 GHz. In both ranges, the effect had a pronounced resonance character with resonance frequencies of 51.76 and 41.32 GHz, respectively [20], [23]. The effect of microwaves did not depend on the sequence of cell exposure to X-rays and MMWs. The MMW effect could not be explained by heating. First, statistically significant suppression of repair was observed at a very low PD of 1 μW/cm^2. Second, no suppression of repair was observed upon heating of cell suspension by 5 °C. Third, the PD averaged over the exposed surface did not depend on frequency within observed resonances.

It was established that the reduction of PD resulted in significant narrowing of the resonance response of *E. coli* cells to MMW exposure [23], [28]. Ups to 15 frequencies were investigated inside each resonance range and all frequency dependencies obtained fitted well to Gaussian distribution [28]. The experimental conditions allowed determination of the resonance frequency with an error of ± 1 MHz. Within this error, the resonance frequency of 51.755 GHz was stable with decreasing of PD from 3×10^{-3} to 10^{-19} W/cm^2. At the same time, the half-width of the resonance decreased from almost 100 to 3 MHz. The dependence of half-width of the 51.755-GHz resonance effect on PD had the steep decrease from 3×10^{-3} to 10^{-7} W/cm^2 followed by slow decreasing from 10^{-7} to 10^{-19} W/cm^2. The question then arose: what happened in the frequency range of 51.65–51.85 GHz upon narrowing of the 51.755-GHz resonance? The cell response to MMWs at a PD of 10^{-10} W/cm^2 was studied in this frequency range [28], [29]. Three additional resonances were detected: 51.675$\pm$0.001, 51.805$\pm$0.002, and 51.835$\pm$0.005 GHz. The half-widths of all resonance including the main one, i.e., 51.755$\pm$0.001 GHz, were about 10 MHz at the PD of 10^{-10} W/cm^2. Therefore, sharp narrowing of the 51.755-GHz resonance in the PD range from 3×10^{-3} to 10^{-7} W/cm^2 was followed by an emergence of new resonances. These data were interpreted as a splitting of the main resonance 51.755 GHz [28]. Dependence of the MMW effect on PD was investigated at one of these resonances, i.e., 51.675 GHz [29]. This dependence had the shape of a "window" in the PD range from 10^{-18} to 10^{-8} W/cm^2. It is important that no MMW effect was observed at subthermal and thermal PDs. This type of PD dependence clearly indicated nonthermal mechanism of the MMW effects observed. The frequency dependencies were studied around 51.675 GHz at different PDs and this resonance frequency was shown to be stable within the range of 10^{-18}–10^{-8} W/cm^2. Along with disappearance of the 51.675-GHz resonance response at a higher PD of 10^{-6}–10^{-3} W/cm^2, a new resonance effect arose at 51.688$\pm$0.002 GHz [29]. This resonance frequency was also stable within the studied PD range. Taken together, these data strongly suggested a sharp rearrangement of resonance spectra, which was induced by MMWs of the subthermal PD range. The half-widths of three studied resonances showed rather different dependencies on the PD, changing from 2 to 3 MHz to 16 to 17 MHz (51.675 and 51.668 GHz) or from 2 to 3 MHz to 100 MHz (51.755 GHz) [28], [29].

Significant narrowing in resonance response was found when studying the growth rate in yeast cells [9] and chromatin conformation in thymocytes of rats [27]. In the study of Gründler *et al.*, the half-width decreased from 16 to 4 MHz as the PD was decreased within the range of 10^{-2}–10^{-12} W/cm^2 [9]. Based on these studies with different cell types, one may assume that narrowing of the resonance upon decease in the PD is one of the basic regularities in cell response to MMWs. On the other hand, different dependencies of a half-width on the PD may be expected for different resonance frequencies.

It was established that the dependence of the MMW effects on the PD had a linear section followed by a plateau [3]. This type of PD dependence was observed in [7], and [10]–[14]. The data obtained in experiments with *E coli* cells and rat thymocytes provided new evidence for this type of PD dependence and indicated that PD dependencies might have the shape of a "window" [22], [27]–[29]. The summary of the data on PD dependencies is given in the Table I. The position of the window varied between different resonance frequencies and depended on cell density during exposure of cells [29]. Nevertheless, window-like PD dependence was observed when studying MMW effect at different resonances. The most striking window was observed at the resonance frequency of 51.755 GHz [28]. When exposing the *E. coli* cells at the cell density of 4×10^8 cell/mL, the effect reached saturation at the PD of 10^{-18}–10^{-17} W/cm^2 and did not change up to PD of 10^{-3} W/cm^2. In these experiments, the direct measurements of PD below 10^{-7} W/cm^2 were not available and lowest PDs were obtained using calibrated attenuators. Osepchuk and Petersen [39] have suggested that MMW effects could be explained by the presence of temporal harmonics, but the body of our data did not support the hypothesis of Osepchuk and Petersen [40]. The background MMW radiation has been estimated as 10^{-21}–10^{-19} W/m^2/Hz [41]. Since the experimentally determined half-width of resonance was in the order of 1 MHz [28], background PD was estimated as 10^{-19}–10^{-17} W/cm^2 within the resonance. The MMW effects were observed at these PD in experiments with *E. coli* cells [24], [26], [28], [29]. The data suggested that the PD dependence of MMW effect might not have a threshold.

TABLE I
WINDOWS IN THE PD DEPENDENCIES OF MMW EFFECTS AS MEASURED WITH THE AVTD TECHNIQUE IN *E. COLI* AND RAT THYMOCYTES

Cells and cell density during exposure, cell/ml	Frequency, GHz	Polarisation	Window in the PD dependence, W/cm^2	Reference
Rat thymocytes, 5x10^6	41.62	linear	10^{-7}-10^{-4}	27
E. coli K12 AB1157, 4x10^7	41.32	circular	10^{-5}-2x10^{-4}	22
X-irradiated *E. coli* K12 AB1157, 4x10^7	41.32	linear	10^{-6}-2x10^{-4}	20
E. coli K12 AB1157, 4x10^7	51.675	linear	10^{-18}-10^{-8}	29
E. coli K12 AB1157, 4x10^8	51.675	linear	10^{-17}-10^{-3}	29
E. coli K12 AB1157, 4x10^7	51.668	linear	10^{-14}-3x10^{-3}	29
E. coli K12 AB1157, 4x10^8	51.668	linear	10^{-8}-10^{-2}	29
E. coli K12 AB1157, 4x10^7	51.755	linear	10^{-18}-10^{-3}	28
E. coli K12 AB1157, 4x10^8	51.755	linear	10^{-19}-10^{-3}	28
E. coli K12 AB1157, 4x10^7	51.674	linear	10^{-17}-10^{-5}	28

IV. DEPENDENCE OF MMW EFFECTS ON DURATION OF EXPOSURE AND TIME AFTER EXPOSURE

Usually, the duration of exposure was 5–10 min in experiments with *E. coli* cells and rat thymocytes at the PD of 10^{-5}–10^{-3} W/cm^2 [20], [21], [27]. In order to achieve the same effect at lower PD of 10^{-14}–10^{-17} W/cm^2, the time of exposure should be prolonged to 20–40 min. This time should be even longer, more than 1 h, at lowest PD of 10^{-19} W/cm^2 [26]. Therefore, the same MMW effect could be achieved by prolongation of exposure if the PD decreased.

The MMW effect on the CCS of *E. coli* cells depended on post-exposure time. Usually, this dependence had an initial phase of increase in the MMW effect. This phase was about 100 min [24], [26] and followed by the phase, which was close to a plateau. The plateau lasted around 100 min [26]. A trend to decrease in effect was observed at longer times up to 300 min [24]. Significant changes in AVTD were observed when rat thymocytes were lyzed in between 30–60 min after exposure to MMWs [27]. This effect nearly disappeared if the cells were incubated more than 80 min after exposure. The data suggested that there is a time window for observation of effect on the CCS, which may be dependent on cell types, cell density during exposure, duration, and PD of exposure.

V. POLARIZATION

The effects of circularly polarized (CP) MMWs were studied in *E. coli* cells at the frequencies from the two resonances identified with linearly polarized MMWs, i.e., 51.62–51.84 and 41.25–41.50 GHz. At the resonance frequency of 51.76 GHz, right-hand CP microwaves suppressed repair of X-rays induced damages as measured with AVTD [21], [23]. Left-hand CP MMWs had virtually no effect on repair, while the efficiency of linearly polarized MMWs was in between two circular polarizations. Inversion in effective circular polarization was observed at another resonance frequency, i.e., 41.32 GHz. Left-hand CP microwaves significantly suppressed repair, while right-hand polarization was almost ineffective. It is important that MMWs of the same CP affected or correspondingly did not affect cells at several tested frequencies within each resonance [22], [21], [23]. Therefore, the sign of effective CP was the attribute of the whole resonance.

In the beginning of experimentation, left- or right-hand spiral waveguides were used to produce CP MMWs [21]. The installation with spiral waveguides provided an ellipticity coefficient of 1.2±0.1. In subsequent experiments, another installation with a better ellipticity coefficient, i.e., 1.05±0.05 was used for exposure [23], [22], [29]. In this installation, CP MMWs was obtained by means of the quarter-wave mica plates. Simultaneous exposure of three different samples with linear, left- and right-hand CP MMWs was available. Stronger difference between effects of left- and right-hand CP MMWs on repair of X-rays-induced damages was observed using installation with the quarter-wave mica plates in comparison to the spiral waveguides [22]. Nevertheless, even with the ellipticity coefficient virtually equal to unity, a statistically significant, though relatively weak, effect of "ineffective" polarization was observed (Table II). This could indicate the presence of a small number of targets in corresponding (nondominant) conformation that are able to interact with MMWs at ineffective polarization. It was found that pre-irradiation of *E. coli* cells to X-rays inverted the sign of effective polarization [22], [23]. This inversion was observed for two resonances (Table II). It is important that neither resonance frequencies, nor half-widths of the resonance changed during inversion of effective CP. The effects of left-and right-hand MMWs become the same at 50 cGy [23]. At this dose, about one single stranded DNA break per haploid genome was induced and the dose was too low to damage significantly any cellular structure, except for DNA. It is known that a nucleoid in *E. coli* cells consists of the supercoiled DNA domains.

TABLE II
EFFECTS OF MICROWAVES AT 100 μW/cm^2 ON THE CHROMATIN CONFORMATIONAL STATE OF INTACT CELLS AND ON REPAIR OF DNA DAMAGES INDUCED BY X-RAYS (20 Gy) AS MEASURED WITH AVTD. ALL EFFECTS WERE NORMALIZED TO THE EFFECT OF THAT TYPE OF CIRCULAR POLARIZATION, WHICH PRODUCED A MAXIMUM EFFECT AT THE GIVEN RESONANCE FREQUENCY. AVERAGE FROM SIX INDEPENDENT EXPERIMENTS AND STANDARD ERROR IS GIVEN. THE DATA WERE ADAPTED FROM [22]

Treatment, polarisation	Resonance 41.32 GHz			Resonance 51.76 GHz		
	Right	Linear	Left	Right	Linear	Left
MMW	1.00±0.08	0.40±0.08	0.08±0.06	0.32±0.08	0.56±0.08	1.00±0.08
MMW and X-rays	0.23±0.12	0.52±0.06	1.00±0.07	1.00±0.06	0.56±0.07	0.28±0.06
X-rays and MMW	0.09±0.09	0.5±0.1	1.0±0.1	1.00±0.04	0.7±0.1	0.24±0.06

It is believed that the majority of DNA in living cells has a right-hand helicity (B-form), but a minor part, in order of 1%, may be in the form of a left-hand helix (Z-form). Radiation-induced DNA breaks result in relaxation of DNA domains. On the other hand, supercoiling is connected with transitions between right-hand B-form to left-hand Z-form in some DNA sequences. Therefore, the data suggested that difference in biological effects of polarized MMWs was connected with DNA helicity and supercoiling of DNA domains.

The supercoiling of DNA domains is changed during the cell cycle because of elementary genetic processes such as transcription, replication, and recombination. It can also be changed by means of DNA-specific intercalators such as ethidium bromide (EtBr). Changing the supercoiling, EtBr facilitates the transition of the left-hand DNA sequences (Z-form) to the right-hand B-form. Preincubation of *E. coli* AB1157 cells with EtBr (1 μg/mL) inverted the effective polarization and right-hand MMWs at the resonance frequency of 51.755 GHz became more effective than left-hand polarization [30]. EtBr changed the supercoiling of DNA domains starting at a concentration of 1 μg/mL, as measured with the AVTD in lysates of different cell types including *E. coli* [28], [37], [38]. The data provided evidence that DNA is a target of MMW effects.

In all experiments, the effect of linear polarized MMWs was in between the effects of two circular polarizations. Unexpectedly, the same circular polarization was more effective if the cells were exposed to MMWs both before and after X-irradiation (Table II). The combined exposure of cells to MMWs at different CP resulted in nonadditive effects [24]. This nonadditivity was explained in terms that each CP stimulated transitions of certain DNA sequences into a form of a corresponding helicity, but the subsequent exposure to MMWs at another polarization might affect this process. More studies are needed to elucidate the mechanism of combined effects of CP MMWs and to characterize the target responsible for dependence of the resonance MMW effects on polarization. Nevertheless, recent investigations of 11 resonances in *E. coli* cells and two resonances in Wistar rat thymocytes indicated that one of two circular polarizations was always more effective than another one [27], [29], [42]. These data are summarized in Table III.

Obviously, the difference in effects of right- and left-hand polarizations could not be explained by heating or by mechanism dealing with "hot-spots" due to unequal SAR distribution. The data about the difference in effects of differently polarized MMWs, inversion of effective circular polarization between resonances, and after irradiation of cells with X-rays, provided clear evidence for nonthermal mechanisms of MMW effects.

VI. MODULATION

There is an experimental evidence for the role of modulation for the microwave-induced effects both *in vitro* and *in vivo* [43]–[45]. Gapeev *et al.* [46] analyzed the role of modulation for the effects of MMWs. The authors studied the respiratory burst induced by calcium ionophore A23187 and phorbol ester PMA in the peritoneal neutrophils of mice. MMWs at the PD of 50 μW/cm^2 inhibited the respiratory burst. MMW effect depended on frequency and was maximal at the frequency of 41.95 GHz. The opposite effect, stimulation of the respiratory burst, was observed upon modulation of MMWs with the frequency of 1 Hz. Only this modulation out of four tested (0.1, 1, 16, and 50 Hz) resulted in stimulation of the respiratory burst.

VII. ELECTROMAGNETIC ENVIRONMENT

Litovitz *et al.* provided evidence that the extremely low-frequency (ELF) magnetic noise of 2 μT inhibited the effects of microwaves on ornithine decarboxylase in L929 cells [45]. Usually, all electric devices were shut down during Gründler *et al.*'s experiments with yeast cells in order to decrease the electromagnetic noise (personal communication). The static magnetic field was controlled in Gründler *et al.*'s experiments and in the replications of these experiments by Gos *et al.* [19]. Background electromagnetic fields might be important for effects of MMWs on the chromatin conformation. This suggestion followed from the observation that both static magnetic field and ELF magnetic fields at low intensities affected the CCS in cells [37], [47], [48]. The changes in static magnetic fields during exposure to MMWs affected response of *E. coli* to MMWs (unpublished results of Shcheglov *et al.*). Therefore, the static magnetic field was controlled and all electric devices were shut down during our experiments with MMWs.

TABLE III
EFFECTIVE POLARIZATION IN RESONANCE RESPONSE OF *E. COLI* CELLS AND WISTAR RAT THYMOCYTES TO NONTHERMAL MMWS AS MEASURED WITH AVTD TECHNIQUE

Cells	Resonance frequency, GHz	Effective circular polarisation
E. coli K12 N99(λ,λ*imm*^{434}*bio*^{10})	41.277±0.002	Right-handed
Wistar rat thymocytes	41.303±0.001	Right-handed
E. coli K12 N99(λ)	41.305±0.001	Right-handed
E. coli K12 AB1157	41.32±0.01	Right-handed
E. coli K12 N99	41.324±0.001	Right-handed
Wistar rat thymocytes	41.61±0.01	Left-handed
E. coli K12 AB1157	51.675±0.001	Left-handed
E. coli K12 N99(λ,λ*imm*^{434}*bio*^{10})	51.723±0.001	Left-handed
E. coli K12 N99(λ)	51.740±0.001	Left-handed
E. coli K12 AB1157	51.755±0.001	Left-handed
E. coli K12 N99	51.765±0.002	Left-handed
E. coli K12 AB1157	51.805±0.002	Right-handed
E. coli K12 AB1157	51.835±0.005	Left-handed

VIII. CELL-TO-CELL INTERACTION IN RESPONSE TO MMWS

Usually, the *E. coli* cells were exposed to MMWs at the cell density of 4×10^7 cell/mL. When the cell density of exposed cells was increased to 4×10^8 cell/mL, the resonance MMW effect grew substantially [26]. Experiments were performed with different PD levels and times of exposure to MMWs at 51.76 GHz. All AVTD measurements were performed at the same cell density of 4×10^7 cell/mL. When the results for the same values of PD and exposure times were compared, the effect of MMWs increased by a factor of 4.7±0.5 on average with increase in cell density by one order of magnitude. The data suggested a cooperative nature of cell response to MMWs, which is based on cell-to-cell interaction during exposure. This suggestion was confirmed by the observed partial synchronization of cells after exposure to MMWs [26]. Due to this synchronization, cell density of the exposed cells could be either higher or lower in comparison to control level in dependence on time after exposure.

A significant MMW effect on synchronization of *Saccharomyces carlsbergensis* yeast cells were observed by Golant *et al.* [49]. Exposure to MMWs at 30 μW/cm^2 and 46 GHz was performed at the cell density of about 10^5 cell/mL. MMWs induced synchronization as measured by cell density and bud formation. This synchronization lasted more than 20 cell cycles after exposure. The authors concluded that MMWs induced cell-to-cell interaction resulting in the synchronization observed.

In recent studies with *E. coli* cells, the cooperative effect was confirmed for the resonance frequency of 51.755 GHz and found at two other resonances of 51.675 and 51.688 GHz [28], [29]. The data suggested that, within different resonances, the response of cells to MMWs might depend on the cell density during exposure. The average intercellular distance was approximately 13 μm at the cell density of 4×10^8 cells/mL. Therefore, no direct physical contact seemed to be involved in the cell-to-cell interaction. Two mechanisms were suggested to account for the cooperative nature in the resonance response to MMWs [26]. In the chemical-diffusional mechanism, the cells, which have responded to MMWs, released chemical messengers. These messengers could reach other cells via diffusion, thus causing secondary reactions. In the electromagnetic mechanism, the affected cells might be a source of a secondary irradiation. The dependence of the effect on cell density was modeled based on both mechanisms, and the electromagnetic one provided better fit to experimental data [26].

Although the dependence of the MMW effect on PD showed considerable difference between two cell densities, 4×10^7 cells/mL and 4×10^8 cells/mL, the 51.755-GHz resonance frequency did not change with changes of cell density [28]. The half-width of the resonance did not depend on cell density either. Contrary to the 51.755-GHz resonance response, the half-width of the 51.675-GHz resonance depended on the cell density [29]. The data suggested that intracellular interaction affected a subcellular target for the effects of MMWs at 51.675 GHz.

The dependence of the resonance response on cell density was studied both at stationary and logarithmic phase of growth during exposure to MMWs in the range of 10^{-18} to 3×10^{-3} W/cm^2 [50]. Relatively weak response to MMWs was observed in exponentially growing cells. Partially synchronized stationary cells were more sensitive, especially at cell densities above 10^8 cell/mL. A significant shift in the resonance frequency was observed between logarithmic and stationary phase. The data suggested that the cooperative response of cells to MMWs might be different at different phases of growth. The data indicated also that response to MMWs might not be limited by the reaction of single cells, but the cooperative reaction of the exposed cell population might be involved. Even at the highest cell densities, the cells occupied a negligible part of the exposed volume and could not change the absorption of microwaves. The significant difference in cell response at the

different cell densities provided strong evidence for nonthermal mechanism of the MMW effects.

IX. Dependence of MMW Effects on Genotype

The effects of MMWs were studied in *E. coli* cells with different length of chromosomal DNA [25]. Bacterial chromosome was lengthened by inserting DNA of λ and $\lambda \mathrm{imm}^{434}\mathrm{bio}^{10}$ phages. Strain N99 of wild type, lysogenic strain N99(λ) and N99($\lambda, \lambda \mathrm{imm}^{434}\mathrm{bio}^{10}$) was used. Response of each strain was studied at 10–17 frequencies inside 41.24–41.37 and 51.69–51.795 GHz at 10^{-10} W/cm^2. Clear resonance response was observed for each strain in both frequency ranges (Table III). Significant shifts of both resonance frequencies were found between strains. The shifted resonances had the same amplitude and half-width as for N99 cells. Upon shifting, no changes in effective circular polarization were observed.

The shifts in resonance frequencies could not be explained by activity of additional genes inserted with the phage DNA. For example, cI and rex genes are active in lysogenic N99(λ) strain. Nevertheless, the $\lambda \mathrm{imm}^{434}\mathrm{bio}^{10}$ insertion did not contain immunity region and, therefore, the cI and rex genes. Moreover, this genome is identical to the genome of phage λ, but about 23% shorter because of bio^{10} deletion. Therefore, it was unlikely that shifts of resonances were caused by additional gene activity upon insertion of $\lambda \mathrm{imm}^{434}\mathrm{bio}^{10}$. On the other hand, the theoretical consideration based on mutual vibrations of separate domains regarding a whole nucleoid provided good correlation between experimental data and calculated shifts in resonances [25].

A detailed analysis of MMW effects in AB1157 cells at 10^{-10} W/cm^2 revealed the resonance frequency of 51.755±0.001 GHz. This value was statistically significantly different from the corresponding resonant frequency of the N99 strain, 51.765±0.002 [28]. It should be noted that both strains are considered as wild-type strains. Nevertheless, those strains were different in genotypes by several specific gene markers [20], [51]. The data suggested that strains of different origin, even being considered of wild type, may posses different resonance responses.

X. Dependence of MMW Effects on Physiological Variables

The importance of physiological parameters, which may include all conditions of cell culture growth such as aeration, the composition of the growth, and exposure media, has been previously discussed by Gründler *et al.* [7]. Recently, Lai and Singh described effects of microwaves on the rat brain cells as measured using a microgel electrophoresis assay [52]. These effects were significantly blocked by treatment of rats either with the spin-trap compound N–tert–butyl–α–phenylnitrone or with melatonin. These data indicated that radicals might be involved in effects of microwaves and provided further evidence for dependence these effects on physiological variables.

In our investigations, *E. coli* cells were exposed to CP or linearly polarized MMWs (100 μW/cm^2) at the resonance frequencies, i.e., 41.32 or 51.76 GHz [24], [26]. Both value and direction of the MMW effects strongly depended on the phase of culture growth. At the logarithmic phase of growth, MMWs at all polarizations resulted in decrease in the AVTD peaks and, contrarily, the AVTD peaks increased after MMW exposure at stationary phase of growth. Higher variability in effects was observed for the logarithmic phase and effects were more stable for the stationary phase. There was no effect at all if cells were exposed at the end of the logarithmic phase where the MMW effects changed their direction [26].

Another stage of particular interest was the beginning of the logarithmic stage, where the effect of MMWs was relatively weak. Nevertheless, only a decrease of AVTD peaks was observed in cell response at different stages of the logarithmic phase. The AVTD data were confirmed by electrophoretic analysis of proteins bound to DNA [24]. The main feature of the effect in the stationary phase was a decrease in the quantity of several DNA-bound proteins with molecular weights of 61, 59, 56, 26, and 15 kDa. The main trend was an increase in some proteins, 61, 56, 51, and 43 kDa, as AVTD peaks decreased after exposure at the logarithmic phase. Thus, the decrease in the level of proteins bound to DNA increased maximum viscosity and vice versa.

The *E. coli* cells were usually grown in Luria broth before exposure to microwaves. Prior to exposure, the cells were collected by centrifuging and suspended in an M9 buffer. In experiments under the same conditions of exposure to MMWs, we observed a dependence of the MMW effect on time between preparation of cell suspension and exposure (Shcheglov *et al.*, in preparation). The control levels of AVTD did not change. The unpublished data of Ushakov *et al.* indicated that the MMW effects correlated with the concentration of oxygen in cell suspension during exposure. This correlation might suggest that oxygen concentration should be indicated in order to improve reproducibility.

XI. Discussion

Our experimental data have revealed several regularities in the effects of the low-intensity microwaves on the chromatin conformation in cells *in vitro*: frequency dependencies of resonance type, dependence of the resonance effects on polarization, "window" dependence on PD, narrowing of the resonances, and rearrangement of frequency spectra of action with decrease in the PD. The MMW effects depended on the genotype of *E. coli* cells under study, the growth stage of the bacterial culture, the cell density, the static magnetic field during exposure, the time between microwave exposure, and recording of the effect. The experimental data provided strong support for nonthermal MMW effects, which have been discovered by Webb and Booth, Vilenskaya *et al.*, Devyatkov, and Gründler *et al.* [1]–[4]. The discussion of mechanisms and biological significance of these effects is beyond the scope of this paper. We would like just to stress that the MMW effects depend on a number of physical, physiological, and genetic parameters. Obviously, not taking into account the dependence of the MMW effects on all those parameters may lead to a negative conclusion regarding the reproducibility. In respect to reproducibility, especially important might be the observations that MMWs could inhibit or stimulate the same functions [14]. Under different conditions of exposure, MMWs either increased or decreased the growth rate

of yeast cells [4]–[9], the radiation-induced damages in mice [52], the respiratory burst in neutrophils of mice [46], and the condensation of nucleoids in *E coli* cells [24], [26]. Potentially bidirectional effects of MMWs should be taken into account to improve reproducibility.

Despite a considerable body of investigations with MMWs in biology, only a few studies were performed to replicate the original data on nonthermal MMW effects. The best-known attempt to replicate the results of Gründler *et al.* was the recent study of Gos *et al.* [19]. No MMW effect was observed in this well-described research. However, a deviation in routine protocol might account for poor reproducibility. For example, synchronized cells were used in studies of Gründler *et al.*Contrary to Gründler *et al.*'s original protocol, exponentially growing cells were used by Gos *et al.*If the MMW effects in yeast cells are dependent on stage of growth, cell density, and intercellular interactions, as described for *E. coli* cells [24], [26], [28], [29], no response might be expected within some stages of the logarithmic phase of growth. Gos *et al.*used a *S. cerevisiae* strain with the auxotrophy mutations for leucine and uracil. The wild type strain was used by Gründler *et al.*. We observed various responses to microwaves between *E. coli* cells with different genotypes, including wild-type strains of different origin. It might suggest another cause for deviations between data of Gründler *et al.* and Gos *et al.*

The number of possible variables in reproducibility of MMW effects seem to be far beyond the limits of usually controlled parameters in biological experiments. Nevertheless, successful application of MMWs in therapy of various diseases [14] provided intriguing perspective for further development of MMWs research in biology and medicine.

ACKNOWLEDGMENT

The authors thank Prof. M. Harms-Ringdahl, Stockholm University, Stockholm, Sweden, for reading the manuscript and fruitful comments.

REFERENCES

[1] S. J. Webb and A. D. Booth, "Microwave absorption by normal and tumour cells," *Science*, vol. 174, pp. 72–74, 1971.
[2] R. L. Vilenskaya, A. Z. Smolyanskaya, V. G. Adamenko, Z. N. Buldasheva, E. A. Gelvitch, M. B. Golant, and D. Y. Goldgaber, "Induction of the lethal colicin synthesis in *E. coli* K12 C600 (E1) by means the millimeter radiation" (in Russian), *Bull. Eksperimental Biol. Med.*, vol. 4, pp. 52–54, 1972.
[3] N. D. Devyatkov, "Influence of electromagnetic radiation of millimeter range on biological objects" (in Russian), *Usp. Fiz. Nauk*, vol. 116, pp. 453–454, 1973.
[4] W. Gründler, F. Keilmann, and H. Frühlich, "Resonant growth rate response of yeast cells irradiated by weak microwaves," *Physiol. Lett.*, vol. 62A, pp. 463–466, 1977.
[5] W. Gründler and F. Keilmann, "Nonthermal effects of millimeter microwaves on yeast growth," *Z. Nat.forsch C*, vol. 33, pp. 15–22, 1978.
[6] ——, "Sharp resonances in yeast growth prove nonthermal sensitivity to microwaves," *Physiol. Rev. Lett.*, vol. 51, pp. 1214–1216, 1983.
[7] W. Gründler, V. Jentzsch, F. Keilmann, and V. Putterlik, "Resonant cellular effects of low intensity microwaves," in *Biological Coherence and Response to External Stimuli*. Berlin, Germany: Springer-Verlag, 1988, pp. 65–85.
[8] W. Gründler and F. Keilmann, "Resonant microwave effect on locally fixed yeast microcolonies," *Z. Nat.forsch. C*, vol. 44c, pp. 863–866, 1989.
[9] W. Gründler, "Intensity- and frequency-dependent effects of microwaves on cell growth rates," *Bioelectrochem. Bioenerg.*, vol. 27, pp. 361–365, 1992.
[10] M. B. Golant, "Resonance effect of coherent millimeter-band electromagnetic waves on living organizms" (in Russian), *Biofizika*, vol. 34, pp. 1004–1014, 1989.
[11] E. Postow and M. L. Swicord, "Modulated fields and "window" effects," in *CRC Handbook of Biological Effects of Electromagnetic Fields*, C. Polk and E. Postow, Eds. Boca Raton, FL: CRC Press, 1986, pp. 425–460.
[12] V. D. Iskin, "Biological effects of millimeter waves and correlation method of their detection" (in Russian), in *Osnova* Kharkov, 1990, p. 244.
[13] I. Y. Belyaev, "Some biophysical aspects of the genetic effects of low intensity millimeter waves," *Bioelectrochem. Bioenerg.*, vol. 27, pp. 11–18, 1992.
[14] A. G. Pakhomov, Y. Akyel, O. N. Pakhomova, B. E. Stuck, and M. R. Murphy, "Current state and implications of research on biological effects of millimeter waves, a review of the literature," *Bioelectromagnetics*, vol. 19, pp. 393–413, 1998.
[15] E. P. Khizhnyak and M. C. Ziskin, "Temperature oscillations in liquid media caused by continuous (nonmodulated) millimeter wavelength electromagnetic irradiation," *Bioelectromagnetics*, vol. 17, pp. 223–229, 1996.
[16] M. A. Rojavin and M. C. Ziskin, "Effect of millimeter waves on survival of UVC-exposed *Escherichia coli*," *Bioelectromagnetics*, vol. 16, pp. 188–196, 1995.
[17] S. M. Motzkin, L. Benes, N. Block, B. Israel, N. May, J. Kuriyel, L. Birenbaum, S. Rosenthal, and Q. Han, "Effects of low-level millimeter waves on cellular and subcellular systems," in *Coherent Excitations in Biological Systems*, H. Frölich and F. Kremer, Eds. Berlin, Germany: Springer-Verlag, 1983, pp. 47–57.
[18] O. P. Gandhi, "Some basic properties of biological tissues for potential biomedical applications of millimeter waves," *J. Microwave Power*, vol. 18, pp. 295–304, 1983.
[19] P. Gos, B. Eicher, J. Kohli, and W. D. Heyer, "Extremely high frequency electromagnetic fields at low power density do not affect the division of exponential phase Saccharomyces cerevisiae cells," *Bioelectromagnetics*, vol. 18, no. 2, pp. 142–155, 1997.
[20] I. Y. Belyaev, Y. D. Alipov, V. S. Shcheglov, and V. N. Lystsov, "Resonance effect of microwaves on the genome conformational state of *E. coli* cells," *Z. Nat.forsch. C*, vol. 47c, pp. 621–627, 1992.
[21] I. Y. Belyaev, V. S. Shcheglov, and Y. D. Alipov, "Existence of selection rules on helicity during discrete transitions of the genome conformational state of *E. coli* cells exposed to low-level millimeter radiation," *Bioelectrochem. Bioenerg.*, vol. 27, pp. 405–411, 1992.
[22] ——, "Selection rules on helicity during discrete transitions of the genome conformational state in intact and X-rayed cells of *E. coli* in millimeter range of electromagnetic field," in *Charge and Field Effects in Biosystems-3*, M. J. Allen, S. F. Cleary, A. E. Sowers, and D. D. Shillady, Eds. Cambridge, MA: Birkhaüser, 1992, pp. 115–126.
[23] I. Y. Belyaev, Y. D. Alipov, and V. S. Shcheglov, "Chromosome DNA as a target of resonant interaction between *Escherichia Coli* cells and low-intensity millimeter waves," *Electro-Magnetobiol.*, vol. 11, pp. 97–108, 1992.
[24] I. Y. Belyaev, V. S. Shcheglov, Y. D. Alipov, and S. P. Radko, "Regularities of separate and combined effects of circularly polarized millimeter waves on *E. coli* cells at different phases of culture growth," *Bioelectrochem. Bioenerg.*, vol. 31, pp. 49–63, 1993.
[25] I. Y. Belyaev, Y. D. Alipov, V. A. Polunin, and V. S. Shcheglov, "Evidence for dependence of resonant frequency of millimeter wave interaction with *Escherichia coli* K12 cells on haploid genome length," *Electro-Magnetobiol.*, vol. 12, pp. 39–49, 1993.
[26] I. Y. Belyaev, Y. D. Alipov, V. S. Shcheglov, V. A. Polunin, and O. A. Aizenberg, "Cooperative response of *Escherichia coli* cells to the resonance effect of millimeter waves at super low intensity," *Electro-Magnetobiol.*, vol. 13, pp. 53–66, 1994.
[27] I. Y. Belyaev and V. G. Kravchenko, "Resonance effect of low-intensity millimeter waves on the chromatin conformational state of rat thymocytes," *Z. Nat.forsch. C*, vol. 49c, pp. 352–358, 1994.
[28] I. Y. Belyaev, V. S. Shcheglov, Y. D. Alipov, and V. A. Polunin, "Resonance effect of millimeter waves in the power range of $10^{-19} - 3 \times 10^{-3}$ W/cm^2 on *E. coli* cells at different concentrations," *Bioelectromagnetics*, vol. 17, pp. 312–321, 1996.

[29] V. S. Shcheglov, I. Y. Belyaev, Y. D. Alipov, and V. L. Ushakov, "Power-dependent rearrangement in the spectrum of resonance effect of millimeter waves on the genome conformational state of *E. coli* cells," *Electro-Magnetobiol.*, vol. 16, pp. 69–82, 1997.
[30] V. L. Ushakov, V. S. Shcheglov, I. Y. Belyaev, and M. Harms-Ringdahl, "Combined effects of circularly polarized microwaves and ethidium bromide on *E. coli* cells," *Electro-Magnetobiol.*, vol. 18, pp. 233–242, 1999.
[31] R. H. Shafer, N. Laiken, and B. H. Zimm, "Radial migration of DNA molecules in cylindrical flow," *Biophys. Chem.*, vol. 2, pp. 180–188, 1974.
[32] V. S. Kryuchkov, V. A. Polunin, Y. D. Alipov, and I. Y. Belyaev, "Physical model of anomalous viscosity time dependence in solutions of high-polymer DNA-protein complexes," *Biofizika*, vol. 40, pp. 1202–1207, 1995.
[33] K. Dill and R. H. Shafer, "Radial migration of DNA molecules in cylindrical flow. II Circles and the effect of non-Gaussian polymer statistics," *Biophys. Chem.*, vol. 4, pp. 51–54, 1976.
[34] K. A. Dill and B. H. Zimm, "A rhelogical separator for very large DNA molecules," *Nucl. Acids Res.*, vol. 7, pp. 735–749, 1979.
[35] K. A. Dill, "Theory for the separation of very large DNA molecules by radial migration," *Biophys. Chem.*, vol. 10, pp. 327–334, 1979.
[36] I. Y. Belyaev and M. Harms-Ringdahl, "Effects of γ-rays in the 0.5-50 cGy range on the conformation of chromatin in mammalian cells," *Radiat. Res.*, vol. 145, pp. 687–693, 1996.
[37] I. Y. Belyaev, Y. D. Alipov, and M. Harms-Ringdahl, "Effects of zero magnetic field on the conformation of chromatin in human cells," *Biochem. Biophys. Acta*, vol. 1336, pp. 465–473, 1997.
[38] I. Y. Belyaev, S. Eriksson, J. Nygren, J. Torudd, and M. Harms-Ringdahl, "Effects of ethidium bromide on DNA loop organization in human lymphocytes determined by anomalous viscosity time dependence and single cell gel electrophoresis," *Biochem. Biophys. Acta*, vol. 1428, pp. 348–356, 1999.
[39] J. M. Osepchuk and R. C. Petersen, "Comments on 'Resonance effect of millimeter waves in the power range from 10^{-19} to 3×10^{-3} W/cm^2 on *Escherichia coli* cells at different concentrations'," *Bioelectromagnetics*, vol. 18, pp. 527–528, 1997.
[40] I. Y. Belyaev, V. S. Shcheglov, Y. D. Alipov, and V. L. Ushakov, "Reply to common of Osepchuk and Petersen," *Bioelectromagnetics*, vol. 18, pp. 529–530, 1997.
[41] N. D. Kolbun and V. Y. Lobarev, "Problems of bioinformational interaction in millimeter range" (in Russian), *Kibern. Vychisl. Tekh.*, vol. 78, pp. 94–99, 1988.
[42] Y. D. Alipov, I. Y. Belyaev, V. G. Kravchenko, V. A. Polunin, and V. S. Shcheglov, "Experimental justification for generality of resonant response of prokaryotic and eukaryotic cells to MM waves of superlow intensity," *Phys. Alive*, vol. 1, pp. 72–80, 1993.
[43] S. Lin-Liu and W. R. Adey, "Low frequency amplitude modulated microwave fields change calcium efflux rates from synaptosomes," *Bioelectromagnetics*, vol. 3, pp. 309–322, 1982.
[44] B. Veyret, C. Bouthet, P. Deschaux, R. de Seze, M. Geffard, J. Joussot-Dubien, M. Le Diraison, J. M. Moreau, and A. Caristan, "Antibody responses of mice exposed to low-power microwaves under combined, pulse-and-amplitude modulation," *Bioelectromagnetics*, vol. 12, pp. 47–56, 1991.
[45] T. A. Litovitz, L. M. Penafiel, J. M. Farrel, D. Krause, R. Meister, and J. M. Mullins, "Bioeffects induced by exposure to microwaves are mitigated by superposition of ELF noise," *Bioelectromagnetics*, vol. 18, no. 6, pp. 422–430, 1997.
[46] A. B. Gapeev, V. S. Iakushina, N. K. Chemeris, and E. E. Fesenko, "Modulated extremely high frequency electromagnetic radiation of low intensity activates or inhibits respiratory burst in neutrophils depending on modulation frequency" (in Russian), *Biofizika*, vol. 42, pp. 1125–1134, 1997.
[47] I. Y. Belyaev, A. Y. Matronchik, and Y. D. Alipov, "The effect of weak static and alternating magnetic fields on the genome conformational state of *E. coli* cells, the evidence for model of phase modulation of high frequency oscillations," in *Charge and Field Effects in Biosystems—4*, M. J. Allen, Ed, Singapore: World Scientific, 1994, pp. 174–184.
[48] I. Y. Belyaev, Y. D. Alipov, and M. Harms-Ringdahl, "Effects of weak ELF on *E. coli* cells and human lymphocytes, role of genetic, physiological and physical parameters," in *Electricity and Magnetism in Biology and Medicine*, F. Bersani, Ed. Norwell, MA: Kluwer, 1999, pp. 481–484.
[49] M. B. Golant, A. P. Kuznetsov, and T. P. Bozhanova, "The mechanism of synchronising yeast cell cultures with EHF-radiation" (in Russian), *Biofizika*, vol. 39, pp. 490–495, 1994.
[50] I. Y. Belyaev, Y. D. Alipov, V. S. Shcheglov, and V. L. Ushakov, "Resonance response of *E. coli* cells to low intensity millimeter waves, dependence on cell density at different phases of growth," in *2nd Word Congr. Elect. Mag. in Biol. Medicine*, Bologna, Italy, 1997.
[51] K. V. Lukashevsky and I. Y. Belyaev, "Switching of prophage lambda genes in *Escherichia coli* by millimeter waves," *Med. Sci. Res.*, vol. 18, pp. 955–957, 1990.
[52] H. Lai and N. P. Singh, "Melatonin and a spin-trap compound block radiofrequency electromagnetic radiation-induced DNA strand breaks in rat brain cells," *Bioelectromagnetics*, vol. 18, pp. 446–454, 1997.
[53] L. A. Sevast'yanova and N. D. Devyatkov, *Nonthermal Effects of Millimeter Radiation* (in Russian). Moscow, Russia: Inst. Radioelectron. USSR Academy Sci., 1981, pp. 86–109.

Igor Y. Belyaev, photograph and biography not available at time of publication.

Victor S. Shcheglov, photograph and biography not available at time of publication.

Eugene D. Alipov, photograph and biography not available at time of publication.

Vadim D. Ushakov, photograph and biography not available at time of publication.

5G; What You Need To Know About 5G Wireless And “Small” Cells
Top 20 Facts About 5G; Environmental Health Trust

What You Need To Know About 5G Wireless And "Small" Cells

Top 20 Facts About 5G

Download a PDF of this information on a two page EHT Factsheet on 5G and Health. The factsheet is hyperlinked (blue text) to research and sources. It is a great resource for policymakers. Read the research on 5G and health here.

Nationwide, communities are being told by wireless companies that it is necessary to build "small cell" wireless facilities in neighborhoods ons street lights and utility poles in order to offer 5G, a new technology that will connect the Internet of Things (IoT). At the local, state, and federal level, new legislation and new zoning aim to streamline the installation of these 5G "small cell" antennas in public rights-of-way.

1. 5G "small" cell antennas are to be placed in neighborhoods everywhere.

- Street lights
- Trashcans
- Utility poles
- Bus stops
- Sides of buildings

2. The radiation from small cells is not small.

Wireless antennas emit microwaves — non-ionizing radiofrequency radiation — and essentially function as cell towers. Each installation can have over a thousand antennas that are transmitting simultaneously. Examples of how small cells are not small include:

- They increase electromagnetic radiation near homes.
- They have refrigerator-sized (and larger) equipment cabinets.
- Property values drop after a cell tower is built near homes.
- Taller and wider poles are needed for the antennas.
- Fixtures weigh hundreds of pounds.

Read the published research on 5G and health here.

NO. Small cell installations are not the size of pizza boxes.
Each installation has antennas on the top and electronics cabinets at the bottom. The electronics are housed in metal boxes – called "street furniture" by industry to make it sound warm and cozy. These cabinets can be ***larger*** than a refrigerator, so large people could fit into them. In addition, there will be various radio units, a smart meter, and potentially unseemly wires.
Most neighborhood light poles are not strong enough to hold the 5G equipment so they will be replaced by much taller wider poles with antennas and 6 ft buzzing boxes. This is called "hardening" the poles but basically it means the poles will be much wider and thicker metal. In Montgomery County as an example, neighborhood, the slim 14 ft light poles will be replaced with hefty 24 ft towers with 300 pound antennas and 6 ft buzzing boxes.

3. Millions of small cells are to be built in front yards in the name of 5G.

The Federal Communications Commission (FCC) estimates and is supporting that millions of these wireless transmitters will be built in our rights-of-way, directly in front of our homes.

4. 5G will add an extra layer — not replace — our current wireless technology.

5G will utilize current 3G and 4G wireless frequencies already in use and also add even more radiation. Higher frequency — submillimeter and millimeter waves — will be used in 5G in order to transmit data at superfast speeds.

5. Community authority is being overruled at every level.

Communities are being stripped of their right to make decisions about this new technology. "Streamlining" means almost automatic approval. Public notice and public hearings are being eliminated. Even if every homeowner on the block opposes the antennas on their street, the opposition will be disregarded with new regulations moving forward at the federal and state level.

Mayors, city officials and public officials are joining to call to halt the federal move to "streamline" the small cells rollout.

"The U.S. Conference of Mayors strongly opposes recent proposals by the Federal Communications Commission to grant communications service providers subsidized access to local public property and to dictate how local governments manage their own local rights-of-ways and public property. This unprecedented federal intrusion into local (and state) government property rights will have

substantial adverse impacts on cities and their taxpayers, including reduced funding for essential local government services, as well as an increased risk of right-of-way and other public safety hazards."

-Statement by U.S. Conference of Mayors CEO & Executive Director Tom Cochran on FCC's Order Proposing to Usurp Local Property Rights Sept. 10th, 2018 | United States Conference of Mayors

6. Cell phone companies have confirmed that 5G "small" cell towers *do not* need to be placed every hundred feet (despite industry statements that densely placed small cells *are needed* in close vicinity to homes).

Verizon's CEO, Lowell McAdam stated on camera that 4G and 5G antennas will work from 3,000 feet away on Macro Towers. This statement proves that Verizon DOES NOT need to place 5G small cells in residential areas every 500 to 1,000 feet.

"When [Verizon] went out in these 11 [5G test] markets, we tested for well over a year, so we could see every part of foliage and every storm that went through. We have now busted the myth that [5G frequencies] have to be line-of-sight — they do not. We busted the myth that foliage will shut [5G] down . . . that does not happen. And the 200 feet from a home? We are now designing the network for over 2,000 feet from transmitter to receiver, which has a huge impact on our capital need going forward. Those myths have disappeared."

-Lowell McAdam, CEO of Verizon

"[Verizon 5G] is really high frequency [28,000 MHz and 39,000 MHz], so everybody thinks it doesn't go very far, but it's a really big pipe and so that's what allows you to gain the super fast speeds . . We're 3,000 feet away from our radio node. the cool thing about this is that we did not move the radio node. . . here even 3,000 feet away, we're still getting 1,000 [Megabits per second] speeds . . . So now we've driven about 1/3 of a mile away [1,760 feet] from the radio node. we are still getting very good speeds even though we have foliage in between [800 Megabits per second]." **-Jason L., Verizon Field Engineer**

7. Scientists worldwide are calling for a halt to the 5G Roll-out.

Scientists from all over the world have issued a declaration calling for a moratorium on the increase of 5G cell antennas citing human health effects and impacts to wildlife.

"We recommend a moratorium on the roll-out of the fifth generation, 5G, for telecommunication until potential hazards for human health and the environment have been fully investigated by scientists independent from industry…RF-EMF has been proven to be harmful for humans and the environment."

— The 5G Scientific Appeal (An Appeal signed by more than 250 scientists and doctors from 35 countries)

- Read the 2017 Scientific Appeal on 5G To the European Commission
- Read the EMF Scientist Appeal published in the International Journal of Oncology.
- Read Letters From Dozens of Scientists on Health Risks of 5G

8. Cumulative daily radiation exposure is associated with serious health effects.

"Effects include increased cancer risk, cellular stress, increase in harmful free radicals, genetic damages, structural and functional changes of the reproductive system, learning and memory deficits, neurological disorders, and negative impacts on general well-being." **– EMF Scientific Appeal**

The public is unaware that peer reviewed, published science indicates that exposures to wireless radiation can cause cancer, alter brain development and damage sperm. Cell tower radiation is also associated with headaches, hormone changes, memory problems and sleep problems.

A review paper published in Environmental Research concludes that the current scientific evidence supports the conclusion that mobile phone and wireless radiofrequency radiation (RFR) is cancer-causing.

Most people are also unaware that wireless technology was never tested for long-term safety decades ago when the technology was first introduced. Children are more vulnerable to this radiation and that the accumulated scientific evidence shows harmful effects.

"There is a substantial body of evidence that this technology is harmful to humans and the environment. The 5G millimeter wave is known to heat the eyes, skin and testes… Of particular concern are the most vulnerable among us — the unborn,

children, the infirm, the elderly and the disabled. It is also expected that populations of bees and birds will drastically decline."

Letter from oncologist Lennart Hardell MD & Colleagues

"A growing body of scientific literature documents evidence of nonthermal cellular damage from non-ionizing wireless radiation used in telecommunications. This RF EMR has been shown to cause an array of adverse effects on DNA integrity, cellular membranes, gene expression, protein synthesis, neuronal function, the blood brain barrier, melatonin production, sperm damage and immune dysfunction". –Dr. Cindy Russell 2018 paper entitled "***5 G wireless telecommunications expansion: Public health and environmental implications."***

Read more published research studies.

9. Scientists state that wireless radiation is a human carcinogen.

Several researchers have published their opinion ***in multiple papers*** that cellular radiation- radiofrequency radiation (the type that cell towers emit) is a human carcinogen based on the current body of science. In 2018, the US National Toxicology Program study peer review scientists concluded"clear evidence of cancer" from cellular radiation exposure in the largest US animal study ever done on the issue. Examples of this published research includes:

- Miller et al., "Cancer Epidemiology Update, following the 2011 IARC Evaluation of Radiofrequency Electromagnetic Fields (Monograph 102)" Environmental Research
- Peleg M, Nativ O, Richter ED. Radio frequency radiation-related cancer: assessing causation in the occupational/military setting. Environmental Research Vol 163, 2018, pp 123–133.
- Hardell, L. and M. Carlberg. Using the Hill viewpoints from 1965 for evaluating strengths of evidence of the risk for brain tumors associated with use of mobile and cordless phones. Rev Environ Health 28:97-106, 2013.
- Evaluation of Mobile Phone and Cordless Phone Use and Glioma Risk Using the Bradford Hill Viewpoints from 1965 on Association or Causation. Carlberg M et al. Biomed Res Int. (2017)

10. Antennas near homes decrease property values.

Studies show property values drop up to 20% on homes near cell towers. Would you buy a home with a mini cell tower in the yard?

Read research studies that show decreased property value from cell towers near homes.

11. Experts state that 5G Small Cell Wireless streaming bills do not make financial sense.

The California Department of Finance rejected California's 5G small cell wireless infrastructure bill S. 649 stating that, "Finance opposes this bill… this bill goes too far by usurping city and county zoning authority for infrastructure development, and it potentially imposes reimbursable, state-mandated costs on cities and counties."

12. Microwave antennas in front yards present several worker and public safety issues.

Unions have already filed comments that workers were injured, unaware they were working near transmitting antennas. How will HVAC workers, window washers, and tree cutters be protected? The heavy large equipment cabinets mounted on poles along our sidewalks also present new hazards. Cars run into utility poles, often, what then? US Department of Labor letters and reports of cell tower health and safety issues.

13. Fiber is the solution and the safe alternative.

Worldwide, many regions are investing in wired fiber optic connections which are are safer, faster, more reliable, provide greater capacity, and are more cyber-secure. Read "Re-Inventing Wires: The Future of Landlines and Networks," by the National Institute for Science, Law & Public Policy

14. Wireless Companies warn investors of risks but neglect to inform consumers and neighbors living near towers.

Crown Castle (a company building small cell infrastructure throughout the USA) has a statement in their 2016 10-K Annual Report that says: "If radio frequency emissions from wireless handsets or equipment on our wireless infrastructure are demonstrated to cause negative health effects, potential future claims could adversely affect our operations, costs or revenues… We currently do not maintain any significant insurance with respect to these matters."

Read similar warnings from Crown Castle, Verizon and other wireless companies in their Annual Reports.

15. Antennas near our homes will affect our sleep.

Wireless radiation alters sleep patterns in replicated research in both animals and humans. For example, an animal study found an hour of exposure to RFR caused a one-hour delay for rats to drift into REM or deep sleep. Human studies have found exposure reduces REM sleep, alters the EEG signal and results in altered performance.

16. Cellular Radiation Negatively Impacts Birds and Bees

Published research finds the frequencies impact wildlife. For example studies have found that the radiation alter bird navigation and disturb honeybee colonies. Research also shows impacts on trees and plant. Research on EMF and Bees. Research on Wildlife Research on Trees

17. US Cities and Entire Countries are voting to halt 5G

Cities such as Petaluma and Mill Valley in California and Doylestown in Pennsylvania have voted and passed policies to halt 5G. Petaluma City Council voted to prohibited small cell installation on city-owned light poles and other city-owned street furniture and established a 500-foot setback from a small cell to any residence. In Mill Valley, schools are zoned as a Community Facility (which captures under the residential code) which prohibits cell towers. Thus schools are protected from 5G antennas in this City. After the Mayor said the 5G small cells would be an "aesthetic disaster" Palm Beach and other coastal communities got entirely carved out of legislation streamlining the 5G antennas.

- Read "California City blocks 5G deployments over cancer concerns"
- Read "Tiny Doylestown Borough battled Verizon over 5G and won a big settlement" and "Tiny Town Rejects Verizon Small Cells and Wins in Court"
- Read Cell tower ordinance read for first time at (Booneville) council meeting, Boonville Democrat
- Read San Rafael residents take pre-emptive strike against 5G installations
- Read "Official: Palm Beach exempt from 5G wireless law"
- Read "**Petaluma 360: Petaluma sets cell phone tower policy"**
- **Read Read "Mill Valley blocks faster, smaller cell phone towers over cancer fears"**SF Gate
- From the Urgent Ordinance from City of Mill Valley – http://cityofmillvalley.granicus.com/MetaViewer.php?view_id=2&clip_id=1290&meta_id=59943

Many countries such as China, India, Poland, Russia, Italy and Switzerland have far

more protective and stricter radiation limits than do we in the United States. These more protective radiation limits will not allow the full deployment of 5G because the increased 5G radiation would exceed these governments allowable levels of radiation. These countries are causing a lot of a headaches for the global telecommunications industry, which has in response launched large-scale public relations efforts to do away with these restrictions. However many countries are holding firm to their limits. For example, in 2018, the Swiss Parliament rejected (22 to 21 votes) loosening the limits for non-ionizing radiation.

- Read "ITU says strict electromagnetic radiation exposure limits may negatively impact 5G roll-out" Telecom Paper 7/2018
- Swisscom Mobile Advertising Campaign for 5G
- Read "Parliament rejects reform of non-ionising radiation rules" March 2018
- Read " Impact of EMF limits on 5G network roll-out" powerpoint presentation by Ericsson that states the 5G rollout is "a major problem or impossible" due to some countries precautionary RF limits.
- Read International Telecommunications Union (ITU) 2018 Report "The impact of RF-EMF exposure limits stricter than the ICNIRP or IEEE guidelines on 4G and 5G mobile network deployment" which states, "Radio frequency electromagnetic field (RF-EMF) exposure limits have become a critical concern for further deployment of wireless networks, especially in countries, regions and even specific cities where RF-EMF limits are significantly stricter than the International Commission for Non-Ionizing Radiation Protection (ICNIRP) or Institute of Electrical and Electronics Engineers (IEEE) guidelines. This problem currently affects several countries such as China, India, Poland, Russia, Italy and Switzerland, regions of Belgium or cities such as Paris.The results of the simulation indicate that where RF-EMF limits are stricter than ICNIRP or IEEE guidelines, the network capacity buildout (both 4G and 5G) might be severely constrained and might prevent addressing of the growing data traffic demand and the launching of new services on existing mobile networks."

The U.S. Conference of Mayors stated that it would sue the FCC if the commission does not change a proposed policy that would preempt local control to streamline 5G.

The National Association of Counties is also opposing the proposal, telling POLITICO it would "effectively prevent local governments from properly examining

the impact that construction, modification or installation of broadcasting facilities may have on public health, safety and welfare of the local community."

Citizens are protesting 5G across the United States and across the world. Watch news videos and learn more about the US at this link on US Bills . News reports across Europe document the opposition to 5G and as an example, citizens protested 5G implementation in Spain with a human chain in Segovia in July 2018. Read "A Human Chain Against 5G."

18. The FCC is not monitoring radiation exposures from cell installations and many cell towers are in violation of the radiation limits.

The Wall Street Journal did an investigative report in 2014 examining over 5,000 cell antennas sites and found that 1 in 10 sites violated the rules during safety audits for carriers and local municipalities "underscoring a safety lapse," yet the FCC has issued just two citations to cell carriers since 1996 because "the FCC says it lacks resources to monitor each antenna." A CBS Atlanta investigation also found radiation excesses up to 400 percent of the limit close up to the antennas on rooftop posing serious health risks especially to any worker coming on the roof.

- Read "Cellphone Boom Spurs Antenna-Safety Worries: Many Sites Violate Rules Aimed at Protecting Workers From Excessive Radio-Frequency Radiation." Wall Street Journal
- "Failure to follow cellular antenna regulations raises safety issues" CBS ATLANTA, Nov 17, 2014

19. The American Academy of Pediatrics is one of many medical organizations that is calling for federal action to protect children. For example, the American Academy of Pediatrics webpage on Cell Towers states:

"An Egyptian study confirmed concerns that living nearby mobile phone base stations increased the risk for developing:

- Headaches
- Memory problems
- Dizziness
- Depression
- Sleep problems"

In fact, the American Academy of Pediatrics (AAP), our largest organization of children's doctors, has repeatedly written the US government that current regulations on cellular radiation are outdated and non protective for children and pregnant women.

"Children are not little adults and are disproportionately impacted by all environmental exposures, including cell phone radiation. Current FCC standards do not account for the unique vulnerability and use patterns specific to pregnant women and children. It is essential that any new standard for cell phones or other wireless devices be based on protecting the youngest and most vulnerable populations to ensure they are safeguarded throughout their lifetimes."

–2013 AAP Letter to the FCC and FDA calling for a review of RF guidelines 8/29/2013

See a list of action and statements by medical organizations here.

20. Firefighters fought hard to oppose 5G small cells in California

The International Association of Firefighters has officially opposed cell towers on their stations since 2004 after a study found neurological damage in firefighters with antennas on their station.

In 2017, when 5G "small cells were coming to California via a 5G streamlining bill (SB649), firefighter organizations came out in strong opposition to the bill and cited the many peer-reviewed studies. They requested that 5G towers not be installed on firehouses. They were successful and SB649 was amended to exempt their stations from the deployment due to their health concerns.

KEY RESEARCH AND REPORTS

5G Frequencies Are Absorbed Into the Skin

Physicists found that the higher millimeter frequencies intended for 5G use are preferentially absorbed into the sweat duct at much higher rates than other organ tissues. Read two published studies "The Modeling of the Absorbance of the Sub-THz Radiation by Human Skin." The human skin as a sub-THz receiver – Does 5G pose a danger to it or not? Paul Ben-Ishai, PhD Lecture.

5G Frequencies Are Used As Weapons

Millimeter frequencies – used in 5G applications- have the capacity to cause a severe burning sensation in the skin and are used by the U.S. Department of Defense in crowd control guns called Active Denial Systems. The frequencies are able to cause this burning sensation due to the way the radiation frequencies are absorbed into the sweat gland.

Landmark US National Toxicology Program (NTP) Study Finds “Clear Evidence of Cancer” and DNA Damage

The NTP studies found male rats exposed for two years to cell phone radiation developed significantly increased gliomas (brain cancer) and schwann cell tumors, the very same types of tumors increased in long-term human cell phone users. NIH/ NTP presentation on DNA results states “exposure to RFR has the potential to induce measurable DNA damage under certain exposure conditions.” Press Coverage, on Peer Review Report

Cell Tower Radiation is Linked To Damage in Human Blood

A published study compared people living close and far from cell antennas and found people living closer to cellular antennas had changes in blood that predicts cancer development. Read Zothansiama et al, 2017. Read a Compilation of Research on Cell Tower Radiation

TAKE ACTION

Contact local, state and federal elected officials in person.

Share this information with your friends, family and community.

Ask for government policy that reduces RFR exposure to the public.

Citizens in all states must organize and take action to halt legislation that increases cell antennas in neighborhoods.

This EHT **fact sheet has links to** to scientific resources and key facts from this page. Please download it and send it to your elected officials and community.

5G Fact sheet in Color

RESOURCES ON US POLICY

Link to Federal Legislation You Can Take Action On

Link to US States With Streamlining Bills You Can Take Action On

CRITICAL LINKS TO INFORMATION ON 5G

Whatis5g.info on the human and environmental impact of 5G

Physicians for Safe Technology

Win19.org Resources on Small Cells and 5G

My Street My Choice: Critical information and links to help residents fight 5G Small Cells.

KEY RESEARCH AND REPORTS

- Link to 5G Frequencies Are Absorbed Into the Skin
- Link to review study that states radiofrequency is a human carcinogen.
- Link to 5G Frequencies Are Used As Weapons
- Link to Landmark US National Toxicology Program (NTP) Study Finds "Clear Evidence of Cancer" and DNA Damage
- Link to Cell Tower Radiation is Linked To Damage in Human Blood
- Link to Published Scientific Review on 5G Finds Adverse Effects
- Link to Cellular Radiation Negatively Impacts Birds
- Link to Cellular Radiation Negatively Impacts Bees

CELL TOWERS

- Link to Overview of Cell Tower Health Effects
- Link to Research on Cell Towers and Health Effects
- Link to Bees, Butterflies and Wildlife
- Link to Impact of Cell Towers on Property Values
- Link to American Academy of Pediatrics on Cell Towers
- Link to Letters from Doctors on Small Cell 5G in Neighborhoods
- Link to Firefighters Oppose Cell Towers on Fire Stations
- Link to Insurance White Papers on Impact of Wireless on Health
- Link to Cell Towers at Schools

- Link to Cell Tower Companies Warn Shareholders of Risk but not People Living Near Their Towers or Using Their Products
- Link to Insurance Company Exclude Electromagnetic Fields as a Standard
- Link to Study Found Damage in Human Blood
- Link to FCC Limits are Non Protective
- Link to 5G Technology
- Link to Cell Tower Worker Safety Issues

SCIENTIFIC STUDIES

- Link to Research on 5G and Cell Tower Radiation
- Link to A 5G Wireless Future: Will it give us a smart nation or contribute to an unhealthy one?" Santa Clara Medical Association Bulletin, Cindy Russell MD, 2017
- Link to Letters by Scientists in Opposition To 5G Research on Cell Tower Radiation, 2017
- Link to Biological Effects from Exposure to Electromagnetic Radiation Emitted by Cell Tower Base Stations and Other Antenna Arrays, Levitt and Lai, 2010
- Link to Radiofrequency radiation injures trees around mobile phone base stations, Waldmann-Selsam et al., 2016
- Link to Department of Interior Letter on the Impact of Cell Towers on Migratory Birds, Willie R. Taylor Director, Office of Environmental Policy and Compliance, 2014
- Link to Anthropogenic radiofrequency electromagnetic fields as an emerging threat to wildlife orientation, Balmori, 2015
- Link to Briefing Memorandum On The Impacts from Thermal and Non-thermal Non-ionizing Radiation to Birds and Other Wildlife, Manville, 2016
- Link to Database of Worldwide International Policy To Reduce EMF
- Link to Youtube Scientific Videos on 5G

More Resources from Physicians for Safe Technology

- League of California Cities City Attorneys' Spring Conference. May 2018. BBK Law. https://www.bbklaw.com/BBK/media/Library/pdf/KARISH-2018-Cal-League-Spring-Attorney-Conference-Paper-vFINAL-c2.pdf

- Cell Tower Zoning and Placement: Navigating Recent FCC Changes 2015. Legal Rights. Cell Tower Zoning: Navigating Recent FCC Changes, National Business Institute Teleconference
- 10 Key Issues for California Cities. Omar Masry. Medium. 10 Key Issues for California Cities and Counties on the Challenges of Small Cells
- Cell Tower Landlord's Checklist: Know Your Rights Amid Mobile Carrier Mega Mergers. BBK Law.
  Cell Tower Landlord's Checklist
- League of Cities Legal Perspective on Telecommunications Law Wireless Antenna Update: Distributed Antenna Systems State and Federal Mandatory Collocation; New Regulatory and Legal Challenges
- Wireless in the Rights of Way and on Private Property. BBK.Law June 2017 Presentation. Wireless in the Rights of Public Way
- Local Authority Over Wireless Facilities in Public Rights-of-Way. April 2018. BBK Legal Letter April 24, 2018
- Cell Towers-Wireless Convenience or Environmental Hazard? (2000) Blake Levitt. She notes that Diane Feinstein did attempt to revise the 1996 Telecommunications Act.
- Biological effects from exposure to electromagnetic radiation emitted by cell tower base stations and other antenna arrays. (2010) Page 374- Biological Effects at Low intensity) Blake Levitt, Henry Lai. Environmental Reviews, 2010, 18(NA): 369-395. http://www.nrcresearchpress.com/doi/full/10.1139/A10-018#.WYUlOHeZNo4

SCIENTIFIC RESOURCES

BioInitiative 2012: A Comprehensive Report by Independent Scientists on the Science of Electromagnetic Radiation

Physicians for Safe Technology

Dr. Moskowitz, University of California at Berkeley

Dr. Lennart Hardell of Örebro University Sweden

The Baby Safe Project: EPA Recognized Awareness Program on Pregnancy and Wireless

"This is a unique situation in the history of the human kind when the whole human

population will be exposed to man-made devices emitting non-ionizing radiation that was insufficiently tested before deployment. What is and what will be the responsibility of the scientists, decision-makers and industry leaders who permit deployment of insufficiently tested technology that will affect us all? The answer is simple – no responsibility… because if any health problems will show up in the future, these will most likely take tens of years of time to manifest and, by then the persons that currently enable deployment of insufficiently tested radiation-emitting 5G technology will be retired or the proverbial 'six feet under.'"

-Dr. Darius Leszczynski, July 18th, 2018 in **Assumption of Safety for 5G by Government Agencies, No Science.**

5G; Millimeter-Wave Cellular Wireless Networks: Potentials and Challenges, IEEE; (2014)

INVITED PAPER

Millimeter-Wave Cellular Wireless Networks: Potentials and Challenges

Over 90% of the allocated radio spectrum falls in the millimeter-wave band (30–300 GHz). Can we make better use of this band to alleviate spectrum crowding at lower frequencies?

By Sundeep Rangan, *Senior Member IEEE*, Theodore S. Rappaport, *Fellow IEEE*, and Elza Erkip, *Fellow IEEE*

ABSTRACT | Millimeter-wave (mmW) frequencies between 30 and 300 GHz are a new frontier for cellular communication that offers the promise of orders of magnitude greater bandwidths combined with further gains via beamforming and spatial multiplexing from multielement antenna arrays. This paper surveys measurements and capacity studies to assess this technology with a focus on small cell deployments in urban environments. The conclusions are extremely encouraging; measurements in New York City at 28 and 73 GHz demonstrate that, even in an urban canyon environment, significant non-line-of-sight (NLOS) outdoor, street-level coverage is possible up to approximately 200 m from a potential low-power microcell or picocell base station. In addition, based on statistical channel models from these measurements, it is shown that mmW systems can offer more than an order of magnitude increase in capacity over current state-of-the-art 4G cellular networks at current cell densities. Cellular systems, however, will need to be significantly redesigned to fully achieve these gains. Specifically, the requirement of highly directional and adaptive transmissions, directional isolation between links, and significant possibilities of outage have strong implications on multiple access, channel structure, synchronization, and receiver design. To address these challenges, the paper discusses how various technologies including adaptive beamforming, multihop relaying, heterogeneous network architectures, and carrier aggregation can be leveraged in the mmW context.

KEYWORDS | Cellular systems; channel models; millimeter-wave radio; urban deployments; wireless propagation; 28 GHz; 3GPP LTE; 73 GHz

I. INTRODUCTION

Demand for cellular data has been growing at a staggering pace, with conservative estimates ranging from 40% to 70% year upon year increase in traffic [1]–[3]. This incredible growth implies that within the next decades, cellular networks may need to deliver as much as 1000 times the capacity relative to current levels. At the same time, as the benefits of wireless connectivity move beyond smartphones and tablets, many new devices will require wireless service—perhaps as many as 50 billion devices will be connected by 2020 in one estimate [4]. Meeting this demand will be a formidable task. Many of the requirements envisioned for what are now being called beyond fourth-generation (4G) and fifth-generation (5G) cellular systems, such as multi-gigabits per second (Gb/s) peak throughputs and tens of megabits per second (Mb/s) cell edge rates [5], are already daunting.

To address this challenge, there has been growing interest in cellular systems for the so-called millimeter-wave (mmW) bands, between 30 and 300 GHz,[1] where the available bandwidths are much wider than today's cellular networks [6]–[9]. The available spectrum at these higher

Manuscript received October 17, 2013; accepted December 26, 2013. Date of publication February 5, 2014; date of current version February 14, 2014. This work was supported by the U.S. National Science Foundation under Grants 1116589 and 1237821 as well as Samsung, Nokia Siemens Networks, Intel, Qualcomm, and InterDigital Communications.

The authors are with the NYU WIRELESS Center, Polytechnic School of Engineering, New York University, Brooklyn, NY 11201 USA (e-mail: srangan@nyu.edu; tsr@nyu.edu; elza@poly.edu).

Digital Object Identifier: 10.1109/JPROC.2014.2299397

[1]While the mmW spectrum is defined as the band between 30 and 300 GHz, industry has loosely considered mmW to be any frequency above 10 GHz

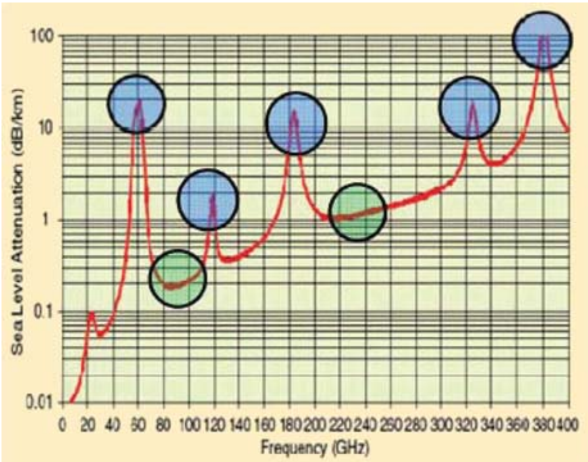


Fig. 1. ***Millimeter-wave (mmW) bands between 30 and 300 GHz offer more than 200 times the spectrum than current cellular allocations, with ample regions with sufficiently low attenuation for small outdoor cells. In bands with the green bubbles, the oxygen attenuation is only a fraction of a decibel greater than free space over distances of several hundred meters. Figure from [6].***

frequencies can be easily 200 times greater than all cellular allocations today that are largely constrained to the prime RF real estate under 3 GHz [6], [8] (see Fig. 1). Moreover, the very small wavelengths of mmW signals combined with advances in low-power complementary metal–oxide–semiconductor (CMOS) radio-frequency (RF) circuits enable large numbers ($\geq$ 32 elements) of miniaturized antennas to be placed in small dimensions. These multiple antenna systems can be used to form very high gain, electrically steerable arrays, fabricated at the base station (BS), in the skin of a cellphone, or even within a chip [6], [10]–[17]. As described in Section II-A, these advances will accelerate with the recent commercialization of 60-GHz Wi-Fi products. This tremendous potential has led to considerable recent interest in mmW cellular both in industry [7]–[9], [18], [19] and academia [20]–[26], with a growing belief that mmW bands will play a significant role in beyond 4G and 5G cellular systems [27].

Despite this activity, this interest in mmW is still very recent and the use of mmW bands remains a largely unexplored frontier for cellular communication. While every other aspect of cellular mobile technology—including processing power, memory, digital communications methods, and networking—have seen tremendous progress since digital cellular systems began some 25 years ago, the carrier frequencies of those systems remain largely the same. With today's severe shortage of spectrum, the time is thus ripe to consider unleashing the capacity in these new bands.

However, the development of cellular networks in the mmW bands faces significant technical obstacles, and the feasibility of mmW cellular communication requires careful assessment. As we will see below, while the increase in omnidirectional path loss due to the higher frequencies of mmW transmissions can be completely compensated through suitable beamforming and directional transmissions, mmW signals can be severely vulnerable to shadowing, resulting in outages and intermittent channel quality. Device power consumption to support large numbers of antennas with very wide bandwidths is also a key challenge.

The broad purpose of this paper is to survey recent results to understand how significant these challenges are, provide a realistic assessment of how mmW systems can be viable, and quantify the potential gain they can provide. We also use the insights from this evaluation to offer guidance on the research directions needed for the realization of next-generation cellular systems in the mmW space.

Since the most significant obstacle to mmW cellular is signal range for non-line-of-sight (NLOS), longer distance links, a large focus on this paper is on outdoor channel measurement studies. In particular, we survey our own measurements [26], [28]–[33] made in New York City (NYC) in both 28- and 73-GHz bands and the statistical models for the channels developed in [34]. NYC provides an excellent test case for mmW propagation studies, since it is representative of a dense, urban outdoor environment where mmW system will likely be initially targeted due to the high user density, small cell radii (typically 100–200 m) and lower mobility. At the same time, NYC is a particularly challenging setting for mmW propagation since the urban canyon topology results in a frequent lack of line-of-sight (LOS) connectivity, severe shadowing, as well as limitations on the height and placement of cells.

As we describe below, our survey of these channel propagation studies shows that, even in a dense, urban NLOS environment, significant signal strength can be detected 100–200 m from a BS with less than 1 W of transmit power. Such distances are comparable to the cell radii in current urban ultrahigh-frequency (UHF)/microwave cells and thus we conclude that mmW systems would not necessarily require greater density for such use cases. In fact, using a recent capacity analysis of ours in [34] that was based on the NYC experimental data, we show that mmW cellular systems can offer at least an order of magnitude increase in capacity relative to current state-of-the-art 4G networks with comparable cell density. For example, it is shown that a hypothetical 1-GHz bandwidth time-division duplex (TDD) mmW system could easily provide a 20-fold increase in average cell throughput in comparison to a 20 + 20-MHz long-term evolution (LTE) system. In cellular systems, where even small increases in capacity can be significant, these gains are truly remarkable.

We also show that the design of a cellular system based in the mmW range will need significant changes, more than just simply scaling the carrier frequency to reach their full potential. Most significantly, communication will

depend extensively on adaptive beamforming at a scale that far exceeds current cellular systems. We show that this reliance on highly directional transmissions has significant implications for cell search, broadcast signaling, random access, and intermittent communication. In addition, due to the particular front–end requirements in the mmW range, support of highly directional communications also has implications for multiple access and support of small packet communications.

A related consequence of highly directional transmissions is that the links become directionally isolated, with interference playing a much smaller role than in current small cell networks. One result is that many of the technologies introduced in the last decade for interference mitigation, such as coordinated multipoint, intercellular interference coordination, and interference alignment, may have limited gains in mmW systems. On the other hand, despite rich multipath and scattering, signal outage may be a larger bottleneck in delivering uniform capacity, and we discuss various alternate technologies, including multihop relaying, carrier aggregation, and heterogeneous networking, to address these issues.

II. MILLIMETER-WAVE CELLULAR NETWORKS

A. The Path to Millimeter-Wave Cellular

For this paper, mmW signals will refer to wavelengths from 1 to 10 mm, corresponding to frequencies approximately in the range of 30–300 GHz. Wireless communications in these mmW bands are not new. Indeed, the first millimeter communications were demonstrated by Bose more than 100 years ago [35]. Currently, mmW bands are widely used for satellite communications [36] and cellular backhaul [37]–[39]. More recently, mmW transmissions have been used for very high throughput wireless local area network (LANs) and personal area network (PAN) systems [6], [40]–[43] in the newly unlicensed 60-GHz bands. While these systems offer rates in excess of 1 Gb/s, the links are typically for short-range or point-to-point LOS settings.

The application of mmW bands for longer range, NLOS cellular scenarios is a new frontier, and the feasibility of such systems has been the subject of considerable debate. While mmW spectrum offers vastly greater bandwidths than current cellular allocations, there is a fear that the propagation of mmW signals is much less favorable. As we will see below, mmW signals suffer from severe shadowing, intermittent connectivity, and will have higher Doppler spreads. Given these limitations, there has been considerable skepticism that mmW bands would be viable for cellular systems that require reliable communication across longer range and NLOS paths [26], [42].

Two recent trends have encouraged a reconsideration of the viability of mmWave cellular. First, advances in CMOS RF and digital processing have enabled low-cost mmW chips suitable for commercial mobiles devices [6], [10], [33]. Significant progress has been made, in particular, in power amplifiers and free space adaptive array combining, and these technologies are likely to advance further with the growth of 60-GHz wireless LAN and PAN systems [6], [40]–[43]. In addition, due to the very small wavelengths, large arrays can now be fabricated in a small area of less than 1 or 2 cm^2. To provide path diversity from blockage by human obstructions (such as a hand holding a part of the device, or the body blocking the path to the cell), several arrays may be located throughout a mobile device.

Second, cellular networks have been evolving toward smaller radii, particularly with support for picocell and femtocell heterogeneous networks in the latest cellular standards [44]–[48]. In many dense urban areas, cell sizes are now often less than 100–200 m in radius, possibly within the range of mmW signals based on our measurements (see Section III).

In the absence of new spectrum, increasing capacity of current networks will require even greater "densification" of cells. While greater densification is likely to play a central role for cellular evolution [47]–[49], building networks beyond current densities may not be cost effective in many settings due to expenses in site acquisition, rollout, and delivering quality backhaul. Indeed, backhaul already represents 30%–50% of the operating costs by some estimates [50], [51], and that share will only grow as other parts of the network infrastructure decrease in price [50], [52], [53]. In contrast, in very high density deployments, the wide bandwidths of mmW signals may provide an alternative to cell splitting by significantly increasing the capacity of individual small cells. Backhaul may also be provided in the mmW spectrum, further reducing costs.

B. Challenges

Despite the potential of mmW cellular systems, there are a number of key challenges to realizing the vision of cellular networks in these bands.

- Range and directional communication: Friis' transmission law [54] states that the free space omnidirectional path loss grows with the square of the frequency. However, the smaller wavelength of mmW signals also enables proportionally greater antenna gain for the same physical antenna size. Consequently, the higher frequencies of mmW signals do not in themselves result in any increased free space propagation loss, provided the antenna area remains fixed and suitable directional transmissions are used. We will confirm this property from our measurements below; see, also, [55]. However, the reliance on highly directional transmissions will necessitate certain design

JA 06412

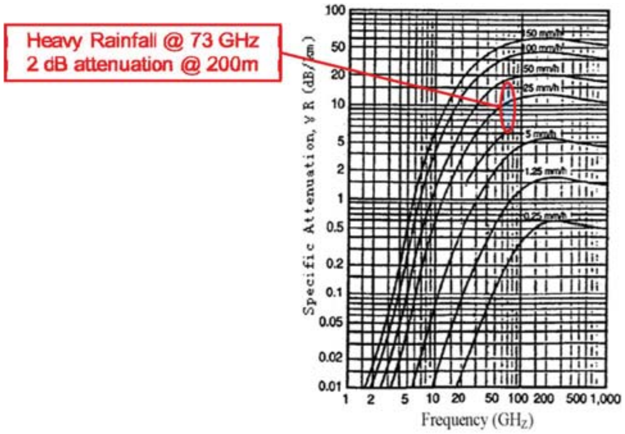


Fig. 2. ***Rain fades: Even in very heavy rainfall, rain fades are typically less than 1 dB per 100 m, meaning they will have minimal impact in cellular systems with cell radii less than 200 m. Figure from [32].***

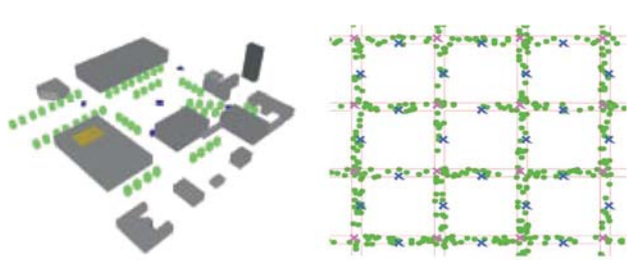
changes to current cellular systems that we discuss in Section V.

- Shadowing: A more significant concern for range is that mmW signals are extremely susceptible to shadowing. For example, materials such as brick can attenuate signals by as much as 40–80 dB [8], [30], [56]–[58] and the human body itself can result in a 20–35-dB loss [59]. On the other hand, humidity and rain fades—common problems for long-range mmW backhaul links—are not an issue in cellular systems; see Fig. 2 and [6] and [26]. Also, the human body and many outdoor materials being very reflective allow them to be important scatterers for mmW propagation [28], [30].
- Rapid channel fluctuations and intermittent connectivity: For a given mobile velocity, channel coherence time is linear in the carrier frequency [54], meaning that it will be very small in the mmW range. For example, the Doppler spread at 60 km/h at 60 GHz is over 3 kHz, hence the channel will change in the order of hundreds of microseconds, much faster than today's cellular systems. In addition, high levels of shadowing imply that the appearance of obstacles will lead to much more dramatic swings in path loss, although beamsteering may overcome this [26]. Also, mmW systems will be inherently built of small cells, meaning that relative path losses and cell association also change rapidly. From a systems perspective, this implies that connectivity will be highly intermittent and communication will need to be rapidly adaptable.
- Multiuser coordination: Current applications for mmW transmissions are generally for point-to-point links (such as cellular backhaul [60]), or LAN and PAN systems [40]–[43] with a limited number of users or MAC-layer protocols that prohibit multiple simultaneous transmissions. However, for high spatial reuse and spectral efficiency, cellular systems require simultaneous transmissions on multiple interfering links, and new mechanisms will be needed to coordinate these transmissions in mmW networks.
- Processing power consumption: A significant challenge in leveraging the gains of multiantenna, wide-bandwidth mmW systems is the power consumption in the analog-to-digital (A/D) conversion. Power consumption generally scales linearly in the sampling rate and exponentially in the number of bits per samples [6], [61], [62], making high-resolution quantization at wide bandwidths and large numbers of antennas prohibitive for low-power, low-cost devices. For example, scaling power consumption levels of even a state-of-the-art CMOS A/D converter designs such as [63] and [64] suggests that A/D converters at rates of 100 Ms/s at 12 b and 16 antennas would require more than 250 mW, a significant drain for current mobile devices. Also, efficient RF power amplification and combining will be needed for phased array antennas.

C. Deployment Models

Due to the limited range of mmW signals, most of the cellular applications for mmW systems have focused on small-cell, outdoor deployments. For example, a capacity study by Pietraski *et al.* [9], [65] considered deployments in campus- and stadium-like settings where the users could obtain relatively unobstructed connections to the mmW cells; see Fig. 3(a).

The focus in this paper will be in urban microcellular and picocellular deployments with cell radii in the range of 100–200 m, similar to current cell sizes for such deployments. Coverage in urban environments will



(a) Campus setting (b) Urban picocell

Fig. 3. ***Millimeter-wave cellular use cases. (a) Outdoor coverage in a campus-like environment, as illustrated in [65]. (b) Urban microcells or picocells as illustrated in a figure detail from [66] showing mmW access points (blue and pink crosses) placed on every block on an urban grid to serve mobiles (green circles) on the streets.***

encounter NLOS propagation much more frequently than outdoor campus or stadium settings, and is thus significantly more challenging. To provide dense coverage in such scenarios, the mmW cells could be deployed, for example, in a picocellular manner on street furniture such as lampposts or sides of buildings to enable direct coverage onto the streets with minimal shadowing. Fig. 3(b) shows such a picocellular layout for an urban environment considered in [66] where one to three mmW access points were placed in each block in a city grid. Other deployments are also possible. For example, cells could be placed similar to current urban microcells on top of buildings for larger area coverage.

D. Heterogeneous Networking Aspects

Due to the inherent limitations of mmW propagation, mmW cellular systems cannot alone provide uniform, robust high capacity across a range of deployments. Millimeter-wave networks will be inherently *heterogeneous*; see Fig. 4. In fact, it is quite likely that cellular and local area networks will blur over time.

Heterogeneous networks, or HetNets, have been one of the most active research areas in cellular standards bodies in the last five years [45], [48], [67], [68], with the main focus being intercell interference coordination and load balancing. However, the introduction of mmW cells into current cellular networks will create heterogeneity in the network in many more aspects than cell size.

- Millimeter-wave and microwave/UHF: Most importantly, since mmW cells will be inherently limited in range (due to the physical limitations of antenna structures and the corresponding gain in a portable device), they will have to coexist with a conventional UHF/microwave cellular overlay for universal coverage.
- Relay versus wired access points: With large numbers of small cells, it may be impractical or expensive to run fiber connectivity to every cell. As we will discuss in Section V-C, relays (or, in a simpler from, repeaters) provide an attractive cost-effective alternative that can build on existing mmW backhaul technology and exploit the full degrees of freedom in the mmW bands.
- Short-range LOS picocells versus NLOS wide-area microcells: As described above, there may be significant differences in coverage between microcells and picocells. Microcells may offer larger range, but more diffuse NLOS coverage. In practice, both cell types will likely need to coexist [30].
- Ownership: A key challenge of mmW is indoor penetration. Reasonable coverage will require that mmW cells be placed indoors [30], [32]. Analogous to the femtocell concept [44]–[48], and neighborhood small cells [69], [70], third parties may be better suited to provide these cells, thereby creating a network with multiple operators and third-party ownership.

Such heterogeneous networks present several design issues, particularly in cell selection and networking. We discuss some of these issues in Section V-F.

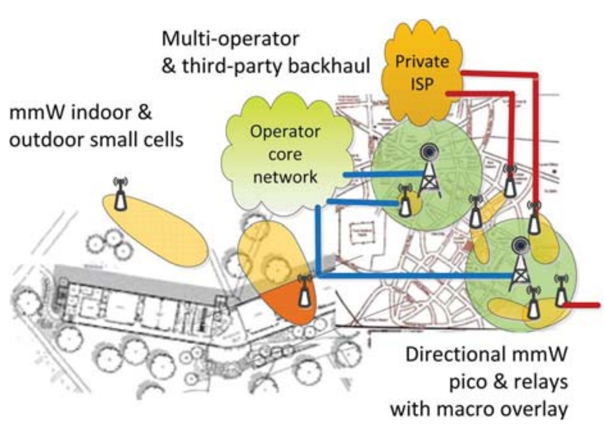


Fig. 4. ***Due to the inherent limitations of mmW propagation, mmW cellular systems will need to coexist and coordinate with conventional microwave cells. Also, to provide indoor coverage and efficiently use the spectrum, backhaul and spectrum may be shared between operators and third parties much more significantly than in current deployments.***

III. CELLULAR CHANNEL MEASUREMENTS

To assess the feasibility of mmW networks, we begin by surveying recent channel measurements of mmW signals in urban environments, particularly our wideband propagation studies in the 28- and 73-GHz bands in NYC.

A. Prior Measurements

Particularly with the development of 60-GHz LAN and PAN systems, mmW signals have been extensively characterized in indoor environments [6], [28], [42], [57], [71]–[75]. The propagation of mmW signals in outdoor settings for microcellular and picocellular networks is relatively less understood.

Due to the lack of actual measured channel data, many earlier studies [7], [9], [22], [23] have relied on either analytic models or commercial ray-tracing software with various reflection assumptions. These models generally assume that propagation will be dominated by either LOS links or links with a few strong specular reflections. As we will see below, these models may be inaccurate.

Also, measurements in local multipoint distribution systems (LMDSs) at 28 GHz—the prior system most close to mmW cellular—have been inconclusive: For example, a study [76] found 80% coverage at ranges up to 1–2 km, while Seidel [77] claimed that LOS connectivity would be required. Our own previous studies at 38 GHz [33], [78]–[81] found

JA 06414

that relatively long-range links (> 750 m) could be established. However, these measurements were performed in an outdoor campus setting with much lower building density and greater opportunities for LOS connectivity than would be found in a typical urban deployment.

B. Measurements in New York City

To provide a realistic assessment of mmW propagation in urban environments, our team conducted extensive measurements of 28- and 73-GHz channels in NYC. Details of the measurements can be found in [26], [28]–[33], [81].

The 28- and 73-GHz bands were selected since they are both likely to be initial frequencies where mmW cellular systems could operate. The 28-GHz bands were previously targeted for LMDSs and are now attractive for initial deployments of mmW cellular, given their relatively lower frequency within the mmW range. However, as mmW systems become more widely deployed, these lower frequency mmW bands will likely become depleted, particularly since they must compete with existing cellular backhaul systems. Expansion to the higher bands is thus inevitable. In contrast, the E-band frequencies (71–76 GHz and 81–86 GHz) [82] have abundant spectrum and are adaptable for dense deployment, providing a major option for carrier-class wireless indoor and outdoor transmission, should the lower frequency become congested. As shown in Fig. 1, the atmospheric absorption of E-band is only slightly worse (e.g., 1 dB/km) than today's widely used lower frequency (UHF/microwave) bands.

To measure the channel characteristics in these frequencies, we emulated microcellular-type deployments where transmitters were placed on rooftops two to five stories high and measurements were then made at a number of street level locations up to 500 m from the transmitters (see Fig. 5). To characterize both the bulk path loss and the spatial structure of the channels, measurements were performed with highly directional, rotatable horn antennas [30-dBm RF output, 10° beamwidths and 24.5-dBi gain at both transmitter (TX) and receiver (RX)]. In order to obtain high time resolution, we employed a 400-Mcps (megachip per second) channel sounder (see Fig. 6). At each TX–RX location pair, the angles of the TX and RX antennas were swept across a range of values to detect discrete clusters of paths [26], [28]–[33], [81].

C. Large-Scale Path Loss Model

Using the data from [26] and [28]–[33], detailed statistical models for the channels were developed in our recent work [34], where we took the directional channel measurements and created narrowband isotropic (unity gain, omnidirectional) channel models by adding the powers received over all measurement angles, and subtracting the 49 dB of original antenna gains used in the measurements. Here, we summarize some of the main findings from [34] to help understand the potential

Fig. 5. *Image from [29] showing typical measurement locations in NYC at 28 GHz for which the isotropic path loss models in this paper are derived. Similar locations were used for the 73-GHz study.*

capacity of mmW systems, and to identify the key design issues [33].

First, we summarize the path loss results. As mentioned above, range is one of the key issues facing mmW systems. Thus, critical to properly assessing mmW systems is to first determine how path loss varies with distance. Toward this end, Fig. 7 (taken from [34]) shows a scatter plot of the estimated omnidirectional path losses at different distances from the transmitter. In both 28- and 73-GHz measurements, each point was classified as either being in a NLOS or LOS situation, based on a manual classification made at the time of the measurements; see [26] and [28]–[33].

In standard urban cellular models such as [83], it is common to fit the LOS and NLOS path losses separately. Fig. 7 shows that the LOS path losses roughly follow the free space propagation based on Friis' law [54], at least for the points with distances < 100 m. For the NLOS points, Akdeniz *et al.* [34] applied a standard linear fit of the form

$$PL(d)\ [\mathrm{dB}] = \alpha + \beta 10 \log_{10}(d) + \xi, \quad \xi \sim \mathcal{N}(0, \sigma^2) \tag{1}$$

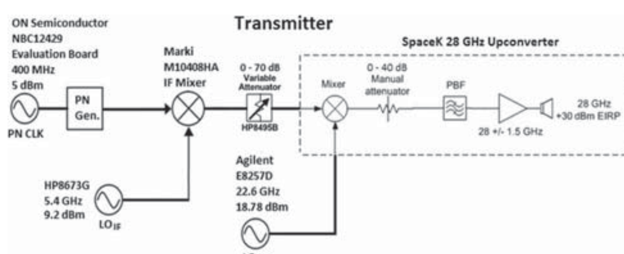


Fig. 6. *The 28-GHz channel sounder transmitter block diagram with 54.5-dBm effective isotropic radiated power (EIRP) and 800-MHz first null-to-null RF bandwidth for high temporal resolution. Figure from [29].*

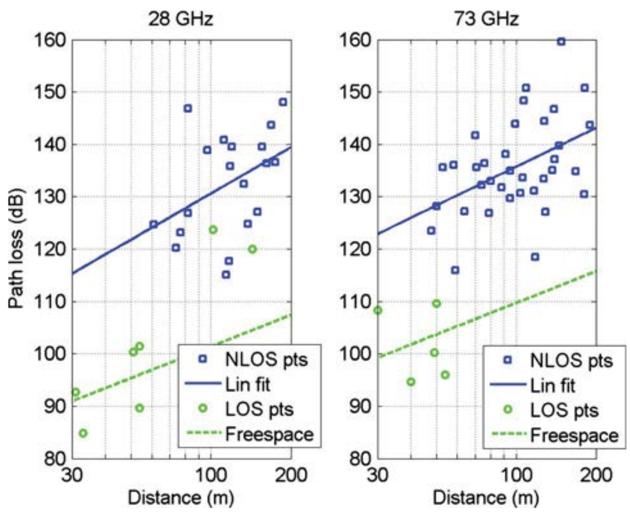


Fig. 7. ***Scatter plot along with a linear fit of the estimated omnidirectional path losses as a function of the TX–RX separation for 28 and 73 GHz. Figure from [34] based on the NYC data in [26].***

where d is the distance in meters, α is the best [minimum mean square error (MMSE)] fit floating intercept point over the measured distances (30–200 m) [81], β is the slope of the best fit, and σ^2 is the lognormal shadowing variance. The parameter values for α, β, and σ are shown in Table 1 along with other parameters that are discussed below.

Note that a close-in free space reference path loss model with a fixed leverage point may also be used, which is equivalent to (1) with the constraint that $\alpha + \beta 10\log_{10}(d_0)$ has some fixed value $PL(d_0)$ for some close-in free space reference d_0. Work in [81] shows that this close-in free space model is less sensitive to perturbations in data and has valuable insights based on propagation physics for the slope parameter β (e.g., $\beta = 2$ is free space propagation and $\beta = 4$ is the asymptotic path loss exponent for a two-ray model). The close-in free space reference model has only a slightly greater (e.g., 0.5-dB larger standard deviation) fitting error. While the analysis below will not use this fixed leverage point, we point this out to caution against ascribing any physical meaning to the estimated values for α or β in (1) when a floating intercept is used.

We can compare the experimentally derived model (1) for the mmW frequencies with those used in conventional cellular systems. To this end, Fig. 8 plots the median omnidirectional path loss for the following models.

- Empirical NYC: These curves are based on the omnidirectional path loss predicted by our linear model (1) for the mmW channel with the parameters from Table 1, as derived from the directional measurements in [26].
- Free space: The theoretical free space path loss is given by Friis' law [54]. We see, for example, that at $d =$ 100 m, the free space path loss is approximately 30 dB less than the omnidirectional propagation model we have developed here based on the directional measurements in [26]. Thus, many of the works such as [9], [22], and [23] that assume free space propagation may be somewhat optimistic in their capacity predictions. Also, it is interesting to point out that one of the models assumed in [7] (PLF1) is precisely free space propagation +20 dB—a correction factor that is 5–10 dB more optimistic than our experimental findings.
- 3GPP UMi: The standard 3GPP urban micro (UMi) path loss model with hexagonal deployments [83]

Table 1 Key Experimentally Derived Model Parameters Used Here and [34] Based on the NYC Data in [26]

Variable	Model	Model Parameter Values	
		28 GHz	73 GHz
Omnidirectional path loss, PL	$PL = \alpha + 10\beta\log_{10}(d) + \xi$, d in meters	$\alpha = 72.0$, $\beta = 2.92$	$\alpha = 86.6$, $\beta = 2.45$
Lognormal shadowing, ξ	$\xi \sim \mathcal{N}(0, \sigma^2)$	$\sigma = 8.7$ dB	$\sigma = 8.0$ dB
Number of clusters, K	$K \sim \max\{Poisson(\lambda), 1\}$	$\lambda = 1.8$	$\lambda = 1.9$
Cluster power fraction	See (3).	$r_\tau = 2.8$, $\zeta = 4.0$	$r_\tau = 3.0$, $\zeta = 4.0$
BS cluster rms angular spread	σ is exponentially distributed, $\mathbb{E}(\sigma) = \lambda^{-1}$	Horiz $\lambda^{-1} = 10.2°$; Vert $\lambda^{-1} = 0°$ (*)	Horiz $\lambda^{-1} = 10.5°$; Vert $\lambda^{-1} = 0°$ (*)
UE rms angular spread	σ is exponentially distributed, $\mathbb{E}(\sigma) = \lambda^{-1}$	Horiz $\lambda^{-1} = 15.5°$; Vert $\lambda^{-1} = 6.0°$	Horiz $\lambda^{-1} = 15.4°$; Vert $\lambda^{-1} = 3.5°$

Note: The model parameters are derived in [34] based on converting the directional measurements from the NYC data in [26], and assuming an isotropic (omnidirectional, unity gain) channel model with the 49 dB of antenna gains removed from the measurements.
(*) BS downtilt was fixed at 10 degree for all measurements, resulting in no measurable vertical angular spread at BS.

JA 06416

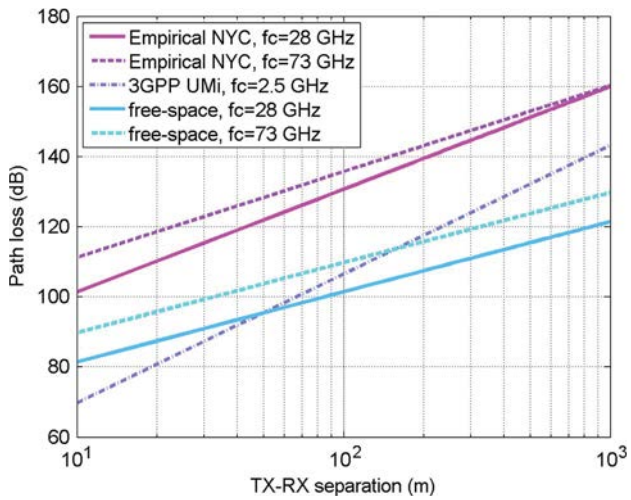


Fig. 8. ***Comparison of distance-based path loss models with unity gain antennas from [34]. The curves labeled "Empirical NYC" are the experimentally derived mmW models based on the NYC data [26]. These are compared to free space propagation for the same frequencies and the 3GPP UMi model [83] for 2.5 GHz.***

is given by

$$PL(d)\ [\text{dB}] = 22.7 + 36.7\log_{10}(d) + 26\log_{10}(f_c) \quad (2)$$

where d is distance in meters and f_c is the carrier frequency in gigahertz. Fig. 8 plots this path loss model at $f_c = 2.5$ GHz. We see that our propagation models for unity gain antennas at both 28 and 73 GHz predict omnidirectional path losses that, for most of the distances, are approximately 20–25 dB higher than the 3GPP UMi model at 2.5 GHz. However, the wavelengths at 28 and 73 GHz are approximately 10–30 times smaller than at 2.5 GHz. Since, for a fixed antenna area, the beamforming gain grows with λ^{-2}, the increase in path loss can be entirely compensated by applying beamforming at either the transmitter or the receiver. In fact, the path loss can be more than compensated relative to today's cellular systems, with beamforming applied at both ends. We conclude that, barring outage events and maintaining the same physical antenna size, mmW propagation does not lead to any reduction in path loss relative to current cellular frequencies and, in fact, may be improved over today's systems. Moreover, further gains may be possible via spatial multiplexing, as we will see below.

D. Angular and Delay Spread Characteristics

The channel sounding system, with 10° beamwidth rotatable horn antennas and 400-MHz baseband signal bandwidth, enables high-resolution time and angular spread measurements. One of the key, and surprising, findings of our studies, was the presence of several distinct clusters of paths with significant angular and delay spread between the clusters. This observation provides strong evidence that—at least with the microcellular-type antennas in an urban canyon-type environment—mmW signals appear to propagate via several NLOS paths rather than a small number of LOS links. We note that these NLOS paths are arriving via reflections and scattering from different buildings and surfaces [26], [28]–[33], [78].

To illustrate the presence of multiple path clusters, the top panel of Fig. 9 shows the measured angular-of-arrival (AoA) power profile at a typical location in our 28-GHz measurements. At this location, we clearly see three angular clusters or "lobes" [31]—a common number observed over all locations. Similarly, the bottom panel shows the power delay profile, and we see that several clusters are apparent.

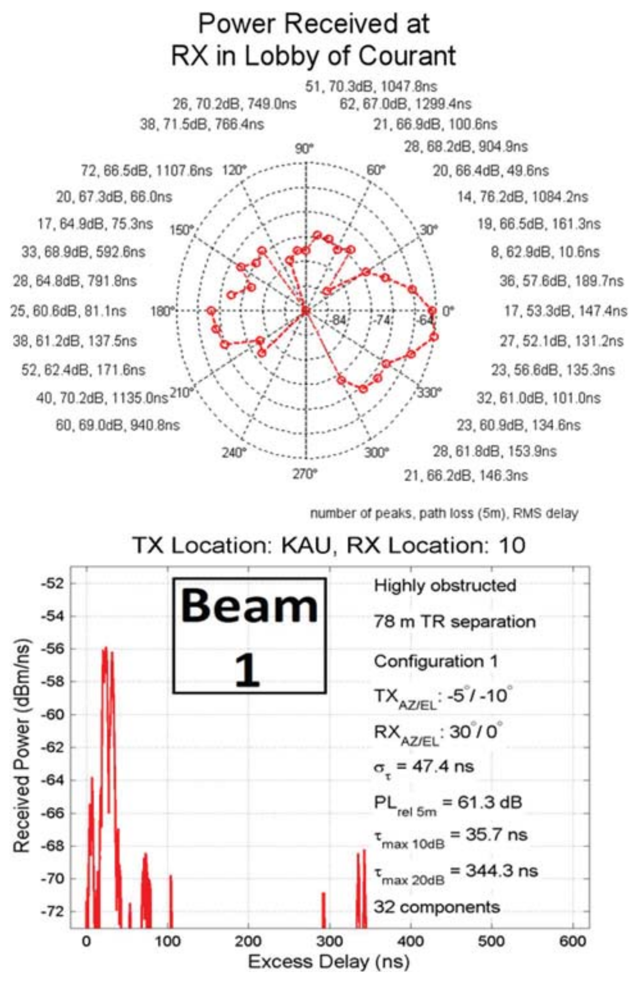


Fig. 9. ***(Top) AoA power profile measured in the courtyard outside a typical building in the 28-GHz measurement campaign. (Bottom) Power delay profile at a different location. Figures from [31] and [55].***

The presence of discrete clusters, each with relatively narrow angular and delay spread, will have certain implications for the receiver design that we discuss in Section V-E.

Akdeniz *et al.* [34] provide a detailed analysis of the statistical properties of the paths clusters, as based on the data [26], [28]–[33]. Some of the findings are as follows.

- The number of clusters is well modeled as a Poisson random variable with an average of approximately two clusters at each location. Due to the presence of multiple clusters and angular spread within clusters, many locations exhibit sufficient spatial diversity to support potentially two or even three spatial degrees of freedom. See [34] for more details.
- The angular spread (both between clusters and within clusters) occurs in the azimuth (horizontal) directions at both the transmitter and the receiver, indicating the presence of local scattering at both ends. Some vertical (elevation) angular spread is also observed at the receivers on the street, potentially from ground reflections. The root-mean-square (rms) beamspread within each cluster can vary significantly and is well modeled via an exponential distribution with similar parameters as current cellular models such as [83].
- The distribution of power among the path clusters is well modeled via a 3GPP model [83] where the fraction of powers in the K clusters are modeled as random variables $\gamma_1, \ldots, \gamma_K$ with

$$\gamma_k = \frac{\gamma_k'}{\sum_{j=1}^K \gamma_j'}, \qquad \gamma_k' = U_k^{r_\tau - 1} 10^{-0.1 Z_k} \qquad (3)$$

  where the first random variable $U_k \sim U[0,1]$ is uniformly distributed and accounts for variations in delay between the clusters (clusters arriving with higher delay tend to have less power), and the second random variable $Z_k \sim \mathcal{N}(0, \zeta^2)$ is Gaussian and accounts for lognormal variations due to difference in shadowing on different clusters. The variables r_τ and ζ are constants fit to the observed power fractions. After fitting the parameters to the data, we found that the main cluster does not have the overwhelming majority of power. Significant power is often found in the second or even third strongest clusters, even considering attenuation due to longer propagation delay [34], again indicating the possibility of spatial multiplexing gains between a single BS and user equipment (UE).

E. Outage Probability

Due to the fact that mmW signals cannot penetrate many outdoor building walls, but are able to reflect and scatter off of them, signal reception in urban environments relies on either LOS links or strong reflections and scattering from building and ground surfaces. Therefore, a key risk in mmW cellular is outage caused by shadowing when no reflective or scattering paths can be found [31], [32].

To assess this outage probability, the study [34] used data from [26] and [28]–[33] which attempted to find signals of suitable strength at a number of locations up to 500 m from the transmitter. Interestingly, the analysis showed that signals were detectable at all 30 locations in Manhattan within 175 m from the cell. However, at locations at distances greater than 175 m, most locations experienced a signal outage. Since outage is highly environmentally dependent, one cannot generalize too much from these measurements. Actual outage may be more significant if there were more local obstacles, if a human were holding the receiver in a handheld device or, of course, if mobiles were indoor. We discuss some of these potential outage effects below.

IV. CAPACITY EVALUATION AND LESSONS LEARNED

Using the experimentally derived channel models from the NYC data [26], Akdeniz *et al.* [34] provided some simple system simulations to assess the potential urban mmW cellular systems. We summarize some of the key findings in that work along with other studies to estimate the possible capacity of mmW systems and identify the main design issues.

A. System Model

Our work here and the work in [34] follow a standard cellular evaluation methodology [83] where the BSs and UEs are randomly placed according to some statistical model, and the performance metrics were then measured over a number of random realizations of the network. Since the interest is in small cell networks, we followed a BS and UE distribution similar to the 3GPP UMi model in [83] with some parameters taken from [7] and [8]. The specific parameters are shown in Table 2. Observe that we have assumed an intersite distance (ISD) of 200 m, corresponding to a cell radius of 100 m. Also, the maximum transmit powers of 20 dBm at the UE and 30 dBm were taken from [7] and [8]. These transmit powers are reasonable since current CMOS RF power amplifiers in the mmW range exhibit peak efficiencies of at least 8%–20% [6], [84], [85].

We considered a network exclusively with mmW cells. Of course, in reality, mmW systems will be deployed with an overlay of conventional larger UHF/microwave cells. Thus, an actual mmW heterogeneous network will have a higher capacity, particularly in terms of cell edge rates. We discuss some of these issues in Section V-F.

To model the beamforming, which is essential in mmW systems, we followed a conservative model, making the simplifying assumption that only single stream processing (i.e., no single-user or multiuser spatial multiplexing) was

JA 06418

Table 2 Default Network Parameters From [34]

Parameter	Description
BS layout and sectorization	Hexagonally arranged cell sites placed in a 2km x 2km square area with three cells per site.
UE layout	Uniformly dropped in area with average of 10 UEs per BS cell (i.e. 30 UEs per cell site).
Inter-site distance (ISD)	200 m
Carrier frequency	28 and 73 GHz
Duplex mode	TDD
Transmit power	20 dBm (uplink), 30 dBm (downlink)
Noise figure	5 dB (BS), 7 dB (UE)
BS antenna	8x8 $\lambda/2$ uniform linear array
UE antenna	4x4 $\lambda/2$ uniform linear array for 28 GHz and 8x8 array for 73 GHz.
Beamforming	Long-term beamforming without single-user or multi-user spatial multiplexing

used. Of course, intercell coordinated beamforming and multiple-input–multiple-output (MIMO) spatial multiplexing [23], [86] may offer further gains, particularly for mobiles close to the cell. Although these gains are not considered here, following [55], we considered multibeam combining that can capture energy from optimally noncoherently combining multiple spatial directions to obtain capacity results here and in [34]. However, we only considered long-term beamforming [87] to avoid tracking of small-scale fading, which may be slightly challenging at very high Doppler frequencies (e.g., bullet trains) at mmW.

Both downlink and uplink assumed proportional fair scheduling with full buffer traffic. In the uplink, it is important to recognize that different multiple-access schemes result in different capacities. If the BS allows one UE to transmit for a portion of time in the whole band, the total receive power will be limited to that offered by a single user. If multiple UEs are allowed to transmit at the same time but on different subbands, then the total receive power will be greater, which is advantageous for users that are not bandwidth limited. The simulations below thus assume that subband frequency-division multiple access (FDMA) is possible. As we discuss in Section V-B, this enables much greater capacity as well as other benefits at the MAC layer. However, realizing such multiple-access systems presents certain challenges in the baseband front–end, which are also discussed.

B. SINR and Rate Distributions

We plot signal-to-interference-plus-noise ratio (SINR) and rate distributions in Figs. 10 and 11, respectively. The distributions are plotted for both 28 and 73 GHz and for 4×4 and 8×8 arrays at the UE. The BS antenna array is held at 8×8 for all cases, although we expect future mmW

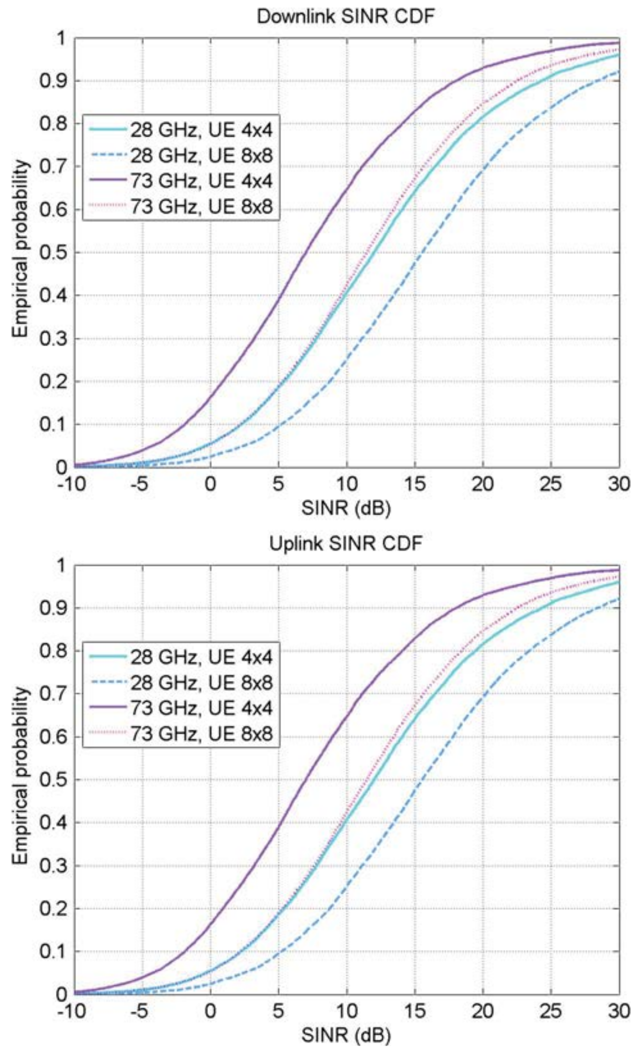


Fig. 10. ***Downlink (top plot)/uplink (bottom plot) SINR CDF at 28 and 73 GHz with 4×4 and 8×8 antenna arrays at the UE. The BS antenna array is held at 8×8. Figure from [34] based on measurement data in [26].***

BSs to have thousands of antenna element leading to much greater gains and directionality. Some of the key statistics are listed in Table 3. More details can be found in [34].

There are two immediate conclusions we can draw from the curves. First, based on this evaluation, the sheer capacity of a potential mmW system is enormous. Cell capacities are often greater than 1 Gb/s and the users with the lowest 5% cell edge rates experience greater than 10 Mb/s. These rates would likely satisfy many of the envisioned requirements for beyond 4G systems such as [5] and [66].

Second, for the same number of antenna elements, the rates for 73 GHz are approximately half the rates for 28 GHz. However, a 4×4 $\lambda/2$-array at 28 GHz would take about the same area as an 8×8 $\lambda/2$ array at 73 GHz. Both would be roughly 1.5×1.5 cm^2, which could be easily accommodated in a handheld mobile device. In addition, we see that 73-GHz

JA 06419

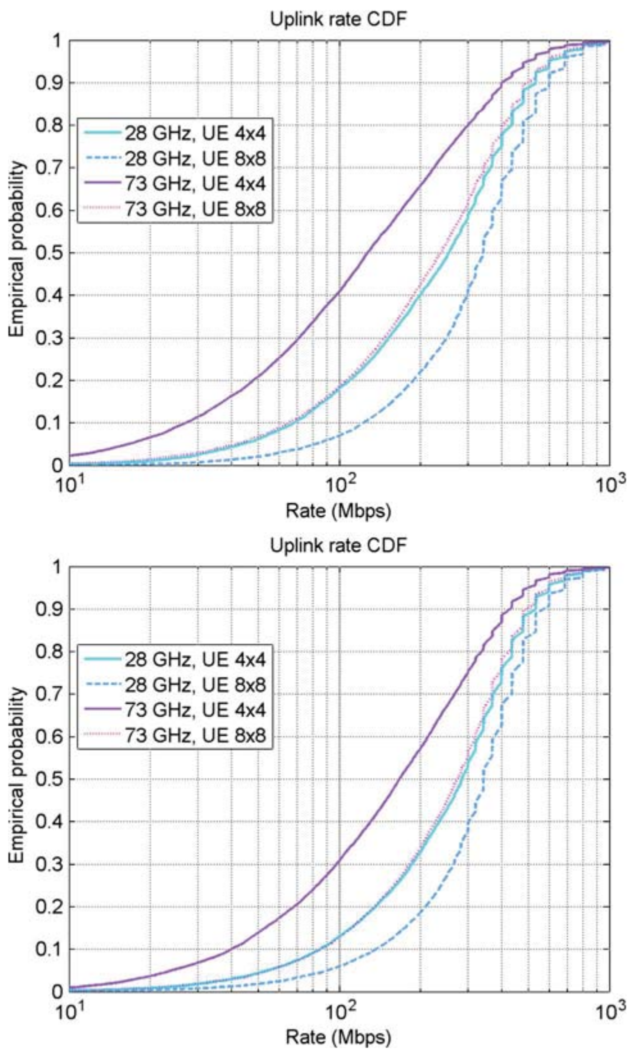


Fig. 11. ***Downlink (top plot)/uplink (bottom plot) rate CDF at 28 and 73 GHz with 4 × 4 and 8 × 8 antenna arrays at the UE. The BS antenna array is held at 8 × 8. Figure from [34] based on measurement data in [26].***

8 × 8 rate and signal-to-noise ratio (SNR) distributions are very close to the 28-GHz 4 × 4 distributions, which is reasonable since we are keeping the UE antenna size approximately constant. Thus, we can conclude that the loss from going to the higher frequencies can be made up from larger numbers of antenna elements without increasing the physical antenna area.

C. Comparison to 4G Capacity

We can compare the SINR distributions in Fig. 10 to those of a traditional cellular network. Although the SINR distribution for a cellular network in a traditional UHF or microwave band is not plotted here, the SINR distributions in Fig. 10 are actually slightly better than those found in cellular evaluation studies [83]. For example, in Fig. 10, only about 10% of the mobiles appear under 0 dB, which is a lower fraction than typical cellular deployments. We conclude that, although mmW systems have an omnidirectional path loss that is 20–25 dB worse than conventional microwave frequencies, short cell radii combined with highly directional beams are able to completely compensate for the loss, and, in fact, improve upon today's systems.

We can also compare the capacity and cell edge rates using the numbers in Table 3. The LTE capacity numbers are taken from the average of industry reported evaluations given in [83] (specifically Table 10.1.1.1-1 for the downlink and Table 1.1.1.3-1 for the uplink). The LTE evaluations include advanced techniques such as spatial-division multiple access (SDMA), although not coordinated multipoint. For the mmW capacity, we assumed 50-50 uplink–downlink (UL–DL) TDD split and a 20% control overhead in both UL and DL directions.

Under these assumptions, we see from Table 3 that the spectral efficiency of the mmW system for either the 28-GHz 4 × 4 array or the 73-GHz 8 × 8 array is roughly comparable to state-of-the art LTE systems.[2] Due to its larger bandwidth, we see in Table 3 (cell capacity) that the mmW systems offer a significant 20-fold increase of overall cell capacity. Moreover, this is a basic mmW system with no spatial multiplexing or other advanced techniques; we expect even higher gains when advanced technologies are applied to optimize the mmW system.

While the 5% cell edge rates are less dramatic, they still offer a ninefold to tenfold increase. This indicates a significant limitation of mmW systems under NLOS propagation; edge of cell users become power limited and are unable to fully exploit the increased spectrum. Thus, other features, such as the use of repeaters/relays, will be needed to achieve a more uniform performance in mmW systems in these scenarios.

D. Interference Versus Thermal Noise

A hallmark of current small cell systems in urban environments is that they are overwhelmingly interference limited, with the rate being limited by bandwidth, and not power. Our studies reveal that mmW small cell systems represent a departure from this model. For example, Fig. 12 plots the distribution of the interference-to-noise ratio (INR) for both uplink and downlink in our simulation of the mmW system at 28 GHz. We see that interference is not dominant. In fact, for the majority of mobiles, thermal noise is comparable or even larger, particularly in the downlink.

At the same time, although interference is not dominant, many of the mobiles are in a bandwidth-limited,

[2]Note that the spectral efficiency for the mmW system is quoted including the 20% overhead, but not the 50% UL–DL duplexing loss. Hence, the cell capacity in Table 3 is $C = 0.5\rho W$, where ρ is the spectral efficiency and W is the baseband bandwidth.

JA 06420

Table 3 Conservative mmW and LTE Cell Capacity/Cell Edge Rate Comparison From [34] Based on Isotropic Channel Models Derived From Measurement Data in [26]

System	BW & Duplex	BS antenna	UE antenna	fc (GHz)	Spec. eff (bps/Hz)		Cell capacity (Mbps)		5% Cell edge rate (Mbps)	
					DL	UL	DL	UL	DL	UL
mmW	1 GHz TDD	8x8	4x4	28	2.25	2.38	1130	1190	17.4	21.6
		8x8	8x8	28	2.83	2.84	1420	1420	32.7	36.3
		8x8	4x4	73	1.45	1.65	730	830	6.6	9.6
		8x8	8x8	73	2.15	2.31	1080	1160	16.6	22.1
LTE	20+20 MHz FDD	2 TX, 4 RX	2	2.5	2.69	2.36	53.8	47.2	1.80	1.94

Note 1. Assumes 20% overhead and 50% UL-DL duty cycle for the mmW system
Note 2. Long-term, non-coherent beamforming are assumed at both the BS and UE in the mmW system. However, the mmW results assume no spatial multiplexing gains, whereas the LTE results from [83] include spatial multiplexing and beamforming.

rather than power-limited regime. For example, Table 3 shows that the average spectral efficiency is approximately 2.1–2.4 b/s/Hz in the uplink and downlink for 4×4 28-GHz or 8×8 73-GHz systems. We find from Table 3 that, if spatial multiplexing is not exploited, links will be bandwidth limited and not power limited, even though interference is not dominant. We conclude that, without spatial multiplexing, mmW systems would represent a new network operating point not seen in current urban cellular deployments: large numbers of mobiles would experience relatively high SINR in directionally isolated links. In a sense, mmW takes us "back to the future" when cellular was first deployed in virgin spectrum.

Of course, without exploiting, spatial multiplexing systems would not benefit from all the degrees of freedom.

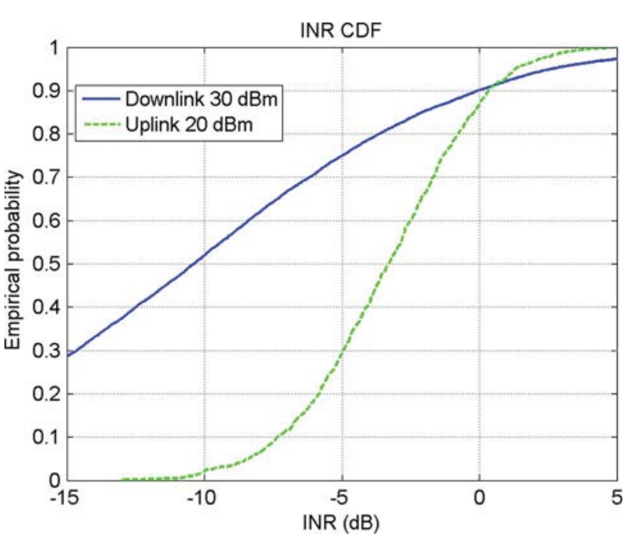


Fig. 12. ***Interference-to-noise ratio in the uplink and downlink for 28 GHz with a 4 × 4 UE antenna array.***

We have not yet evaluated single-user or multiuser MIMO, but such techniques would lower the SINR per stream for the higher SINR mobiles. However, the INR distribution would not significantly change since the total transmit power would be constant. Therefore, the links would remain limited by thermal noise rather than interference.

E. Effects of Outage

As mentioned above, one of the significant risks of mmW systems is the presence of outage; the fact that there is a nonzero probability that the signal from a given BS can be too weak to be detectable.

To quantify this effect, Akdeniz *et al.* [34] estimated the capacity under various outage probability models. The simulations above assumed that at distances greater than a threshold of $T = 175$ m, the signal would not be detectable, and, hence, the link would be in outage. This assumption was based on the data we observed in [26] and [28]–[33]. However, as discussed in Section III-E, mobiles in other environments may experience outages closer to the cell, particularly if there is a lot of ground clutter or the humans themselves blocking the signal. To model this scenario, Akdeniz *et al.* [34] considered a hypothetical outage model, loosely based on [83], where there was a significant outage probability even close to the cell. For example, in this model (called a "soft outage" for reasons explained in [34]), there was approximately a 20% probability that a link to a cell would be in outage even when it was only 80 m from the cell.

Interestingly, under this more conservative outage model, the average cell capacity was not significantly reduced. However, both uplink and downlink 5% cell edge rates fell by a dramatic 50%. This reduction shows that mmW systems are robust enough that mobiles in outage to any one cell will still be able to establish a connection to another cell. On the other hand, in environments where the outages close to the cell are frequent, the gains of

mmW systems will not be nearly as uniform, with cell edge users suffering significantly.

F. Other Studies

Although our study here and in [34] was the first to use the experimentally derived omnidirectional channel models from the directional data in [26], the results in [34] roughly corroborate the findings of very high capacity from mmW systems predicted in several earlier analyses. For example, the study in [7] estimated approximately 300 Mb/s per cell throughput in a 500-MHz system. This capacity corresponds to a somewhat lower spectral efficiency than what we show here and in [34], but the study in [7] assumed only minimal beamforming at the receiver (either no beamforming or a 2×2 array) and a much larger cell radius of 250 m.

In [9], ray-tracing software is used to analyze a mmW campus network, and a median total system capacity of 32 Gb/s with five cell sites, each cell site having four cells, is found. Since the bandwidth in that study was 2 GHz, the spectral efficiency was approximately $2/5/4/2\ 3 = 0.8$ b/s/Hz/cell. This number again is lower than our predictions, but [9] was limited to quadrature phase-shift keying (QPSK) modulation. Somewhat higher capacity numbers were found in a followup study [65] in both campus and urban environments. A later study presented in [66] predicted average spectral efficiencies of almost 1.5 b/s/Hz in a 2-GHz system in an urban grid deployment, a number only slightly lower than our value of 2.3–2.8 b/s/Hz. In all these studies, the cell edge rates compare similarly to the predicted values in [34], assuming one normalizes to the number of users in each cell.

In a different work, Akoum *et al.* [22] used a stochastic geometry analysis and predicted almost 5.4 b/s/Hz, which is almost twice our estimated spectral efficiency. However, that work assumed that all links can operate at the Shannon limit with no maximum spectral efficiency.

This comparison illustrates that, in a number of different scenarios and analysis methods, the absolute spectral efficiency and cell edge rate numbers are roughly comparable with estimates here and in [34] that used experimentally derived channel models. Thus, the broad message remains the same: under a wide variety of simulation assumptions, mmW systems can offer orders of magnitude increases in capacity and cell edge rate over state-of-the-art systems in current cellular bands.

V. KEY DESIGN ISSUES AND DIRECTIONS FOR mmW 5G

The above preliminary results show that while mmW bands offer tremendous potential for capacity, cellular systems may need to be significantly redesigned. In this section, we identify several key design issues that need to be addressed from a systems perspective if the full gains of mmW cellular systems are to be achieved.

A. Directional Transmissions and Broadcast Signaling

The most obvious implication of the above results is that the gains of the mmW system depend on highly directional transmissions. As we discussed above, directionality gains with appropriate beamforming can completely compensate for, and even further reduce, any increase in the omnidirectional path loss with frequency. Indeed, once we account for directional gains enabled by smaller wavelengths, the path loss, SNR, and rate distributions in the mmW range compare favorably with (and may improve upon) those in current cellular frequencies.

One particular challenge for relying on highly directional transmissions in cellular systems is the design of the synchronization and broadcast signals used in the initial cell search. Both BSs and mobiles may need to scan over a range of angles before these signals can be detected. This "spatial searching" may delay BS detection in handovers—a point made in a recent paper [88]. Moreover, even after a mobile has detected a BS, detection of initial random access signals from the mobile may be delayed since the BS may need to be aligned in the correct direction.

A related issue is supporting intermittent communication [say through discontinuous reception and transmission (DRX and DTX) modes] which has been essential in standards such as LTE for providing low power consumption with "always on" connectivity [89]. In order that either a mobile or a BS can quickly begin transmitting, channel state information in the form of the spatial directions will need to be maintained at the transmitter. If cells are small, even the second-order spatial statistics of the channel may change relatively fast implying that some sort of intermittent transmissions may need to be performed to track the channel state.

B. Multiple-Access and Front–End/Baseband Considerations

With small cells, the need for future spectrum/bandwidth flexibility, support for beamforming and low cost, TDD is an attractive duplexing strategy for mmW. Our analysis in Table 3 assumes TDD for mmW.

However, closely related to the issue of directional transmissions is how to support FDMA within the TDD time slots. Current cellular systems use digital processing for MIMO and beamforming. However, with the large numbers of antennas and wide bandwidths, it is simply not practical from a power or cost perspective to place high-resolution, wideband A/D converters on each antenna element in the mmW range [6]–[8]. Most commercial designs have thus assumed phased-array architectures where signals are combined either in free space or RF with phase shifters [90]–[92] or at IF [93]–[95] prior to the A/D conversion. A limitation of such architectures is that they

JA 06422

will forgo the support of spatial multiplexing and multiuser transmissions within the TDD time slots and require time-division multiple access (TDMA) with only one user within a time slot being scheduled at a time. In particular, FDMA transmissions within the same time slot as supported in LTE through resource blocks will not be possible; see Fig. 13.

Enabling granular allocations in frequency is one of the main hallmarks of LTE, and sacrificing this capability by restricting to TDMA scheduling will bear significant costs in mmW.

- Uplink power: Restricting to TDMA scheduling within a TDD time slot implies that the power of only UE can be received at a time. Since mobiles at the cell edge may be power limited, this reduction of power can significantly reduce capacity. For example, according to the uplink rate cumulative distribution function shown in Fig. 14, one can easily see an order of magnitude improvement when multiuser transmission is enabled by FDMA, compared to a baseline TDMA, both assuming TDD.
- Support for small packets: Supporting multiuser transmissions will also be essential to efficiently support messages with small payloads and is needed for low latency machine-to-machine communications [96]. Specifically, when only one UE can transmit or receive at a time, it must be allocated in the entire bandwidth in a TDD slot, which is extremely wasteful for small packets. As an example, in the design of [8], the transmission time interval (TTI) is 125 μs. Thus, a 1-GHz allocation at this TTI will have approximately 125 000 degrees of freedom. Such large transport blocks would be terribly inefficient, for example, for transport control protocol acknowledgment as well as other control signaling.

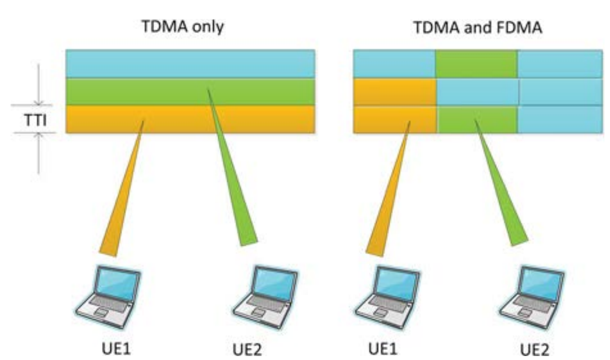


Fig. 13. ***Multiple access: Enabling FDMA (within a TDD time slot), where multiple UEs can be scheduled at a time, can offer numerous benefits in mmW systems, including improved power in the uplink, more efficient transmission of small packets, and reduced UE power consumption. A key design issue is how to support FDMA in TDD with mmW front-ends that perform beamsteering in analog.***

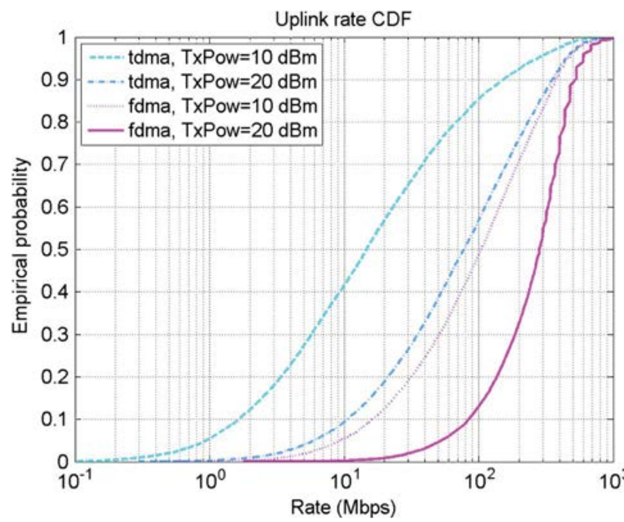


Fig. 14. ***Power loss with TDMA only: Designs that do not enable multiple users to be scheduled at the same time can suffer a significant penalty in capacity in the uplink due to loss of power. Shown here is the rate distribution comparing FDMA and TDMA scheduling using beamforming with the 28-GHz isotropic channel model.***

- Power consumption: From a power consumption perspective, it may be preferable for individual UEs to only process only a smaller portion (say 100 MHz) of the band during a time slot. Such subband allocations can reduce the power consumption of the baseband processing, which generally scales linearly in the bandwidth.

Thus, a key design issue facing 5G mmW systems is how to support multiple access while enabling low power consumption, particularly at the UE. One promising route has been the use of compressed sensing and other advanced low-bit rate technologies, suggested in [97].

In addition, one may consider other SDMA algorithms that optimally exploit a smaller number of beams. For example, each UE can still support only one digital stream, potentially on a subband for low power consumption. The BS, which would generally have somewhat higher power capacity, could support a smaller number, say K, beams. Then, to support N UEs with $K<N$, the BS can simply select the K beams to span the "best" K-dimensional subspace to capture the most energy of the N users.

C. Directional Relaying and Dynamic Duplexing

Another key design issue for mmW cellular systems is support for repeaters/relays—a feature that can be particularly valuable due to the need for range extension. In current cellular systems, relaying has been primarily used both for coverage extension and, to a lesser extent, capacity expansion when backhaul is not available [99]–[101]. Although significant research went into enabling relaying in 3GPP LTE-Advanced [102], the projected gains have been modest. In dense interference-limited environments, the

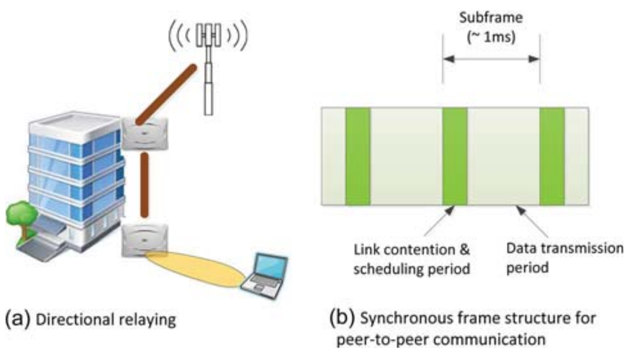


Fig. 15. ***Directional mmW relaying. (a) Multihop directional relaying can provide wireless backhaul and extend coverage of mmW signals in the presence of clutter and shadowing. (b) A synchronous peer-to-peer frame structure along the lines of [98] can enable fast coordination and resource allocation across relays, BSs, and mobiles with dynamic duplexing.***

loss in degrees of freedom with half-duplex constraints and multiple transmissions is typically not worth the increase in received power from shorter range.

With regards to relaying, mmW networks may be fundamentally different. As discussed above, one of the greatest challenges for mmW systems is that mobiles may be in outage to the closest cell, dramatically reducing the cell edge rate. In these cases, relaying may be necessary to selectively extend coverage to certain users and provide a more uniform quality of service throughout the network. Furthermore, given the inability of mmW signals to penetrate indoors, relaying would also be essential to provide seamless indoor/outdoor coverage and coverage in and around vehicles, airplanes, etc. Relaying may also be valuable for backhaul to picocells when fiber connectivity is not available [37]–[39]. Depending on the cell locations, some of these mmW links may be in the clutter and require NLOS connectivity similar to the access links; see, for example, Fig. 15(a).

In order to obtain the full advantages of relaying, cellular systems may need to be significantly redesigned. Cellular systems have traditionally followed a basic paradigm dividing networks into distinct BSs and mobiles, with relays typically being added as an afterthought. However, given the central role that relaying may play in the mmW range for both the access link and for backhaul, it may be worth investigating new peer-to-peer topologies, such as Qualcomm's FlashLinQ system [98], where there is less centralized scheduling and where frequency band and time slots are not statically preallocated to traffic in any one direction. As shown in Fig. 15(b), one may consider symmetric frame structures that are common in the uplink and downlink. The directions of the links would not necessarily need to be synchronized across the network, and a periodic contention period can be used to reassign the directions of the links as necessary. Such a design would be a significant departure from the uplink–downlink in current LTE systems, but would enable much greater flexibility for multihop networks and integrated systems for both access and backhaul.

D. An End to Interference?

As mentioned above, current cellular networks in dense urban deployments are overwhelmingly interference limited. At a high level, mitigating this interference can be seen as the driving motivation behind many of the advanced technologies introduced into cellular systems in the last decade. These techniques include coordinated multipoint, intercellular interference coordination and more forward-looking concepts such as interference alignment.

One of the striking conclusions of the above analysis is that many of these techniques may have much more limited gains in the mmW space. As we saw, for many mobiles, thermal noise is significantly larger than interference. That is, in mmW systems with appropriate beamforming, links become directionally isolated and intercellular interference is greatly reduced. This fact implies that point-to-point, rather than network, technologies may play a much larger role in achieving capacity gains in these systems.

E. Exploiting Channel Sparsity and Compressed Sensing

As described in Section II-B, one possible challenge in mmW system is the high Doppler. In general, Doppler spread is a function of the total angular dispersion, carrier frequency, and mobile velocity [54]. Thus, due to the high carrier frequencies and significant local scattering, one might initially think that the total Doppler spread in mmW systems will be high and potentially difficult to track.

However, the measurements reviewed in Section III revealed that signals generally arrive on a small number of path clusters, each with relatively small angular spread. Directional antennas will further reduce the multipath angular spread [103]. This property implies that the individually resolvable multipath components will vary very slowly, a fact confirmed directly in our experiments in [26]. This is good news.

To understand how to exploit these slow variations for tracking the channel, first observe that the narrowband channel response at any particular frequency could be described as

$$h(t) = \sum_{k=1}^{K} g_k(t) e^{2\pi i f_d \cos(\theta_k) t} \tag{4}$$

where K is the number of clusters, f_d is the maximum Doppler shift, θ_k is the central angle of arrival of the

JA 06424

cluster, and $g_k(t)$ is the time-varying gain of the channel related to the angular spread *within* the cluster. Since the angular spread within each cluster is small, the cluster gains $g_k(t)$ will generally be slowly varying even though the aggregate channel $h(t)$ may have much higher variations. Moreover, the angles of arrival θ_k are also typically slowly varying since they are a result of the large-scale scattering environment and do not change with small-scale mobility. This fact suggests that even though $h(t)$ may change rapidly, the parametrization (4) may enable more accurate tracking, particularly since the number of clusters K tends to be small (K is typically 1–5 in our measurements).

The parametrization (4) is fundamentally *nonlinear* and analogous to the types of models used in finite rate of innovation models [104] and compressed sensing-based channel estimation and channel sounding [105]–[108]. The extension of these methods to very wideband systems with large numbers of antennas may, therefore, have significant value.

F. Heterogeneous Networking Issues

As described in Section II-C, mmW systems cannot be deployed in a standalone manner. To provide uniform, reliable coverage, fallback to cellular systems in conventional UHF or microwave frequencies will be necessary. While support for heterogeneous networks has been a key design goal in recent cellular standards, mmW systems will push the need for support for heterogeneous networks in several new directions.

Most importantly, the heterogeneous network support in mmW will require cell selections and path switching at much faster rates than current cellular systems. Due to their vulnerability to shadowing, mmW signals to any one cell will be inherently unreliable and can rapidly change with small motions of the users or the user's environment. One avenue to explore is the use of *carrier aggregation* techniques [109], [110] where mobiles can connect to multiple BSs simultaneously. Carrier aggregation was introduced in release 10 of 3GPP LTE-Advanced primarily to increase peak throughputs. For mmW systems, carrier aggregation could provide macrodiversity, but would require support for path switching and scheduling in the network.

A second issue in the evolution of HetNets for mmW will be multioperator support. Indoor cells and cells mounted on private buildings may be better operated by a third party who would then provide roaming support for carriers from multiple subscribers. While roaming is commonly used in current networks, the time scales for mmW roaming would be much faster. In addition, with carrier aggregation, it may be desirable for a mobile to be connected to cells from different operators simultaneously.

Further complicating matters is the fact that, given the large amount of spectrum, a single operator may not be able to fully utilize the bandwidth. Thus, the model where a single operator has exclusive rights to a bandwidth may not lead to the most efficient use of the spectrum. However, support for multiple operators sharing spectrum will need much more sophisticated intercell interference coordination mechanisms, especially with directionality. Future clearing houses will provide such measurement and management for multiple carriers and their users.

VI. CONCLUSION

Millimeter systems offer tremendous potential with orders of magnitude greater spectrum and further gains from high-dimensional antenna arrays. To assess the feasibility of mmW systems, we have presented some initial propagation measurements in NYC—a challenging environment, but representative of likely initial deployments. Our measurements and capacity analysis have revealed several surprising features: Through reflections and scattering, mmW signals are potentially viable at distances of 100–200 m, even in completely NLOS settings. Moreover, with modest assumptions on beamforming, our capacity analysis has indicated that mmW systems can offer at least an order of magnitude in capacity over current state-of-the-art LTE systems, at least for outdoor coverage.

Potential mmW cellular systems may need to be significantly redesigned relative to current 4G systems to obtain the full potential of mmW bands. In particular, the heavy reliance on directional transmissions and beamforming will necessitate reconsideration of many basic procedures such as cell search, synchronization, random access, and intermittent communication. Multiple access and channelization also become tied to front–end requirements, particularly with regard to analog beamforming and A/D conversion.

In addition, directional isolation between links suggests that interference mitigation, which has been a dominant driver for new cellular technologies in the last decade, may have a less significant impact in mmW. On the other hand, technologies such as carrier aggregation and multihop relaying that have had only modest benefits in current cellular networks may play a very prominent role in the mmW space. These design issues—though stemming from carrier frequency—span all the layers of communication stack and will present a challenging, but exciting, set of research problems that can ultimately revolutionize cellular communication. ■

Acknowledgment

The authors would like to thank several students and colleagues for providing the propagation data [26], [29]–[33], [55] and capacity analysis [34] that made this research possible: M. Riza Akdeniz, Y. Azar, F. Gutierrez, D. D. Hwang, Y. Liu, R. Mayzus, G. MacCartney, S. Nie, M. K. Samimi, J. K. Schulz, S. Sun, K. Wang, G. N. Wong, and H. Zhao. This work also benefitted significantly from

discussions with authors' industrial affiliate partners in NYU WIRELESS, including Samsung, Intel, NSN, Qualcomm, and InterDigital. This work also benefitted from discussions from several researchers, including J. Andrews, G. Caire, M. Chiang, R. Heath, U. Madhow, and W. Yu, as well as the anonymous comments from the reviewers.

REFERENCES

[1] Cisco, "Cisco visual network index: Global mobile traffic forecast update," 2013.

[2] Ericsson, "Traffic and market data report," 2011.

[3] UMTS Forum, "Mobile traffic forecasts: 2010–2020 report," 2011, vol. 44.

[4] Ericsson, "More than 50 billion connected devices," White Paper. [Online]. Available: http://www.ericsson.com/res/docs/whitepapers/wp-50-billions.pdf

[5] P. E. Mogensen, K. Pajukoski, B. Raaf, E. Tiirola, L. Eva, I. Z. Kovacs, G. Berardinelli, L. G. U. Garcia, L. Hu, and A. F. Cattoni, "B4G local area: High level requirements and system design," in *Proc. IEEE Globecom Workshop*, Dec. 2012, pp. 613–617.

[6] T. S. Rappaport, J. N. Murdock, and F. Gutierrez, "State of the art in 60-GHz integrated circuits and systems for wireless communications," *Proc. IEEE*, vol. 99, no. 8, pp. 1390–1436, Aug. 2011.

[7] F. Khan and Z. Pi, "Millimeter wave mobile broadband (MMB): Unleashing the 3–300 GHz spectrum," in *Proc. 34th IEEE Sarnoff Symp.*, Mar. 2011, DOI: 10.1109/SARNOF.2011.5876482.

[8] F. Khan and Z. Pi, "An introduction to millimeter wave mobile broadband systems," *IEEE Commun. Mag.*, vol. 49, no. 6, pp. 101–107, Jun. 2011.

[9] P. Pietraski, D. Britz, A. Roy, R. Pragada, and G. Charlton, "Millimeter wave and terahertz communications: Feasibility and challenges," *ZTE Commun.*, vol. 10, no. 4, pp. 3–12, Dec. 2012.

[10] C. Doan, S. Emami, D. Sobel, A. Niknejad, and R. Brodersen, "Design considerations for 60 GHz CMOS radios," *IEEE Commun. Mag.*, vol. 42, no. 12, pp. 132–140, Dec. 2004.

[11] C. Doan, S. Emami, A. Niknejad, and R. Brodersen, "Millimeter wave CMOS design," *IEEE J. Solid-State Circuits*, vol. 40, no. 1, pp. 144–155, Jan. 2005.

[12] Y.-P. Zhang and D. Liu, "Antenna-on-chip and antenna-in-package solutions to highly integrated millimeter wave devices for wireless communications," *IEEE Trans. Antennas Propag.*, vol. 57, no. 10, pp. 2830–2841, Oct. 2009.

[13] F. Gutierrez, S. Agarwal, K. Parrish, and T. S. Rappaport, "On-chip integrated antenna structures in CMOS for 60 GHz WPAN systems," *IEEE J. Sel. Areas Commun.*, vol. 27, no. 8, pp. 1367–1378, Oct. 2009.

[14] J. Nsenga, A. Bourdoux, and F. Horlin, "Mixed analog/digital beamforming for 60 GHz MIMO frequency selective channels," in *Proc. IEEE Int. Conf. Commun.*, 2010, DOI: 10.1109/ICC.2010.5502689.

[15] S. Rajagopal, S. Abu-Surra, Z. Pi, and F. Khan, "Antenna array design for multi-gbps mmwave mobile broadband communication," in *Proc. Global Telecommun. Conf.*, 2011, DOI: 10.1109/GLOCOM.2011.6133699.

[16] K.-C. Huang and D. J. Edwards, *Millimetre Wave Antennas for Gigabit Wireless Communications: A Practical Guide to Design and Analysis in a System Context*. New York, NY, USA: Wiley, 2008.

[17] F. Rusek, D. Persson, B. K. Lau, E. Larsson, T. Marzetta, O. Edfors, and F. Tufvesson, "Scaling up MIMO: Opportunities and challenges with very large arrays," *IEEE Signal Process. Mag.*, vol. 30, no. 1, pp. 40–60, Jan. 2013.

[18] S. Hur, T. Kim, D. J. Love, J. V. Krogmeier, T. A. Thomas, and A. Ghosh, "Millimeter wave beamforming for wireless backhaul and access in small cell networks," 2013, arXiv preprint. [Online]. Available: arXiv: 1306.6659

[19] Samsung, "Samsung announces worlds first 5G mmwave mobile technology," May 2013, press release. [Online]. Available: http://global.samsungtomorrow.com/?p=24093

[20] G. Fettweis and R. Irmer, "WIGWAM: System concept development for 1 Gbit/s air interface." [Online]. Available: https://mns.ifn.et.tu-dresden.de/Lists/nPublications/Attachments/362/Fettweis_G_WWRF_05.pdf

[21] J. Laskar, S. Pinel, D. Dawn, S. Sarkar, B. Perumana, and P. Sen, "The next wireless wave is a millimeter wave," *Microw. J.*, vol. 50, no. 8, pp. 22–34, 2007.

[22] S. Akoum, O. E. Ayach, and R. W. Heath, "Coverage and capacity in mmWave MIMO systems," in *Proc. Asilomar Conf. Signals Syst. Comput.*, Pacific Grove, CA, USA, Nov. 2012, DOI: 10.1109/JPROC.2011.2155190.

[23] H. Zhang, S. Venkateswaran, and U. Madhow, "Channel modeling and MIMO capacity for outdoor millimeter wave links," in *Proc. IEEE Wireless Commun. Netw. Conf.*, Apr. 2010, DOI: 10.1109/WCNC.2010.5506714.

[24] E. Torkildson, H. Zhang, and U. Madhow, "Channel modeling for millimeter wave MIMO," in *Proc. Inf. Theory Appl. Workshop*, Feb. 5, 2010, DOI: 10.1109/ITA.2010.5454109.

[25] H. Zhang and U. Madhow, "Statistical modeling of fading and diversity for outdoor 60 GHz channels," in *Proc. Int. Workshop mmWave Commun., From Circuits to Networks*, Sep. 2010, pp. 45–50.

[26] T. S. Rappaport, S. Sun, R. Mayzus, H. Zhao, Y. Azar, K. Wang, G. N. Wong, J. K. Schulz, M. Samimi, and F. Gutierrez, "Millimeter wave mobile communications for 5G cellular: It will work!," *IEEE Access*, vol. 1, pp. 335–349, 2013.

[27] F. Boccardi, R. W. Heath, A. Lozano, T. L. Marzetta, and P. Popovski, "Five disruptive technology directions for 5G," *IEEE Commun. Mag.*, 2014.

[28] E. Ben-Dor, T. S. Rappaport, Y. Qiao, and S. J. Lauffenburger, "Millimeter wave 60 GHz outdoor and vehicle AOA propagation measurements using a broadband channel sounder," in *Proc. IEEE Global Telecommun. Conf.*, 2011, DOI: 10.1109/GLOCOM.2011.6133581.

[29] Y. Azar, G. N. Wong, K. Wang, R. Mayzus, J. K. Schulz, H. Zhao, F. Gutierrez, D. Hwang, and T. S. Rappaport, "28 GHz propagation measurements for outdoor cellular communications using steerable beam antennas in New York City," in *Proc. IEEE Int. Conf. Commun.*, 2013, pp. 5143–5147.

[30] H. Zhao, R. Mayzus, S. Sun, M. Samimi, J. K. Schulz, Y. Azar, K. Wang, G. N. Wong, F. Gutierrez, and T. S. Rappaport, "28 GHz millimeter wave cellular communication measurements for reflection and penetration loss in and around buildings in New York City," in *Proc. IEEE Int. Conf. Commun.*, 2013, pp. 5163–5167.

[31] M. Samimi, K. Wang, Y. Azar, G. N. Wong, R. Mayzus, H. Zhao, J. K. Schulz, S. Sun, F. Gutierrez, and T. S. Rappaport, "28 GHz angle of arrival and angle of departure analysis for outdoor cellular communications using steerable beam antennas in New York City," in *Proc. IEEE Veh. Technol. Conf.*, 2013, DOI: 10.1109/VTCSpring.2013.6691812.

[32] S. Nie, G. R. MacCartney, Jr., S. Sun, and T. S. Rappaport, "72 GHz millimeter wave indoor measurements for wireless and backhaul communications," in *Proc. IEEE Int. Symp. Pers. Indoor Mobile Radio Commun.*, Sep. 2013, pp. 2429–2433.

[33] T. S. Rappaport, F. Gutierrez, E. Ben-Dor, J. N. Murdock, Y. Qiao, and J. I. Tamir, "Broadband millimeter wave propagation measurements and models using adaptive-beam antennas for outdoor urban cellular communications," *IEEE Trans. Antennas Propag.*, vol. 61, no. 4, pp. 1850–1859, Apr. 2013.

[34] M. R. Akdeniz, Y. Liu, M. K. Samimi, S. Sun, S. Rangan, T. S. Rappaport, and E. Erkip, "Millimeter wave channel modeling and cellular capacity evaluation," Dec. 2013. [Online]. Available: http://arxiv.org/abs/1312.4921

[35] J. Bose, *Collected Physical Papers*. New York, NY, USA: Longmans, Green and Co., 1927.

[36] D. Roddy, *Satellite Communications*, 4th ed. New York, NY, USA: McGraw-Hill, 2006.

[37] J. Hansry, J. Edstam, B.-E. Olsson, and C. Larsson, "Non-line-of-sight microwave backhaul for small cells," *Ericsson Rev.*, Feb. 2013.

[38] NGMN Alliance, "Small cell backhaul requirements," White Paper, Jun. 2012. [Online]. Available: http://www.ngmn.org/uploads/media

[39] Electronic Communications Committee (ECC), "Fixed service in Europe current use and future trends," 2012. [Online]. Available: http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCRep173.PDF

[40] E. Perahia, C. Cordeiro, M. Park, and L. Yang, "IEEE 802.11ad: Defining the next generation multi-Gbps Wi-Fi," in *Proc. IEEE Consum. Commun. Netw. Conf.*, Jan. 2010, DOI: 10.1109/CCNC.2010.5421713.

[41] S. J. Vaughan-Nichols, "Gigabit Wi-Fi is on its way," *IEEE Computer*, vol. 43, no. 11, pp. 11–14, Nov. 2010.

[42] R. Daniels, J. Murdock, T. S. Rappaport, and R. Heath, "60 GHz wireless: Up close and personal," *IEEE Microw. Mag.*, vol. 11, no. 7, pp. 44–50, Dec. 2010.

[43] T. Baykas, C.-S. Sum, Z. Lan, J. Wang, M. A. Rahman, H. Harada, and S. Kato,

"IEEE 802.15.3c: The first IEEE wireless standard for data rates over 1 Gb/s," *IEEE Commun. Mag.*, vol. 49, no. 7, pp. 114–121, Jul. 2011.

[44] S. Ortiz, "The wireless industry begins to embrace femtocells," *IEEE Comput.*, vol. 41, no. 7, pp. 14–17, Jul. 2008.

[45] V. Chandrasekhar, J. G. Andrews, and A. Gatherer, "Femtocell networks: A survey," *IEEE Commun. Mag.*, vol. 46, no. 9, pp. 59–67, Sep. 2009.

[46] S.-P. Yeh, S. Talwar, S.-C. Lee, and H. Kim, "WiMAX femtocells: A perspective on network architecture, capacity, and coverage," *IEEE Commun. Mag.*, vol. 46, no. 10, pp. 58–65, Oct. 2008.

[47] Femto Forum, "Interference management in OFDMA femtocells," White Paper, Mar. 2010. [Online]. Available: www.femtoforum.org

[48] J. G. Andrews, H. Claussen, M. Dohler, S. Rangan, and M. C. Reed, "Femtocells: Past, present, and future," *IEEE J. Sel. Areas Commun.*, vol. 30, no. 3, pp. 497–508, Apr. 2012.

[49] Qualcomm, "The 1000× challenge: More small cells—Taking HetNets to the next level," 2013. [Online]. Available: http://www.qualcomm.com/solutions/wirelessnetworks/technologies/1000x-data/small-cells

[50] H. Claussen, L. T. W. Ho, and L. Samuel, "Financial analysis of a pico-cellular home network deployment," in *Proc. IEEE Int. Conf. Commun.*, Jun. 2007, pp. 5604–5609.

[51] Senza Fili Consulting, "Crucial economics for mobile data backhaul," White Paper, 2011. [Online]. Available: http://cbnl.com/sites/all/files/userfiles/files/CB-002070-DC-LATEST.pdf

[52] D. Webster, "Solving the mobile backhaul bottleneck," Apr. 2009. [Online]. Available: http://blogs.cisco.com/sp/solving_the_mobile_backhaul_bottleneck

[53] C. Mathias, "Fixing the cellular network: Backhaul is the key," Dec. 2008. [Online]. Available: http://www.networkworld.com/community/print/35920

[54] T. S. Rappaport, *Wireless Communications: Principles and Practice*, 2nd ed. Upper Saddle River, NJ, USA: Prentice-Hall, 2002.

[55] S. Sun and T. S. Rappaport, "Multi-beam antenna combining for 28 GHz cellular link improvement in urban environments," in *Proc. IEEE Global Telecommun. Conf.*, Dec. 2013.

[56] K. Allen, N. DeMinco, J. R. Hoffman, Y. Lo, and P. B. Papazian, "Building penetration loss measurements at 900 MHz, 11.4 GHz, and 28.8 MHz," U.S. Dept. Commerce, National Telecommun. Inf. Admin. (NTIA), Boulder, CO, USA, Rep. 94-306, 1994.

[57] C. R. Anderson and T. S. Rappaport, "In-building wideband partition loss measurements at 2.5 and 60 GHz," *IEEE Wireless Commun. Mag.*, vol. 3, no. 3, pp. 922–928, May 2004.

[58] A. Alejos, M. Sanchez, and I. Cuinas, "Measurement and analysis of propagation mechanisms at 40 GHz: Viability of site shielding forced by obstacles," *IEEE Trans. Veh. Technol.*, vol. 57, no. 6, pp. 3369–3380, Nov. 2008.

[59] J. S. Lu, D. Steinbach, P. Cabrol, and P. Pietraski, "Modeling human blockers in millimeter wave radio links," *ZTE Commun.*, vol. 10, no. 4, pp. 23–28, Dec. 2012.

[60] S. Chia, M. Gasparroni, and P. Brick, "The next challenge for cellular networks: Backhaul," *IEEE Microw. Mag.*, vol. 10, no. 5, pp. 54–66, May 2009.

[61] T. Cho, D. Cline, C. Conroy, and P. Gray, "Design considerations for low-power, high-speed CMOS analog/digital converters," in *Proc. IEEE Symp. Low Power Electron.*, Oct. 1994, pp. 70–73.

[62] J. Murdock and T. S. Rappaport, "Consumption factor and power-efficiency factor: A theory for evaluating the energy efficiency of cascaded communication systems," *IEEE J. Sel. Areas Commun.*, 2013, DOI: 10.1109/JSAC.2014.141204.

[63] C.-Y. Chen, J. Wu, J.-J. Hung, T. Li, W. Liu, and W.-T. Shih, "A 12-bit 3 GS/s pipeline ADC with 0.4^2mm and 500 mW in 40 nm digital CMOS," *IEEE J. Solid-State Circuits*, vol. 47, no. 4, pp. 1013–1021, Apr. 2011.

[64] H.-L. Park, Y.-G. Kwon, M.-H. Choi, Y. Kim, S.-H. Lee, Y.-D. Jeon, and J.-K. Kwon, "A 6b 1.2 GS/s 47.8 mW 0.17 mm^2 65 nm CMOS ADC for high-rate WPAN systems," *J. Semicond. Sci. Technol.*, vol. 11, no. 2, pp. 95–103, Jun. 2011.

[65] M. Abouelseoud and G. Charlton, "System level performance of millimeter-wave access link for outdoor coverage," in *Proc. IEEE Wireless Commun. Netw. Conf.*, 2013, pp. 4146–4151.

[66] A. Ghosh, "Can mmwave wireless technology meet the future capacity crunch?" *IEEE Int. Conf. Commun.*, Budapest, Hungary, Jun. 2013. [Online]. Available: http://www.ieee-icc.org/2013/Mmwave_Spring_ICC2013_Ghosh.pdf

[67] Qualcomm, LTE Advanced: Heterogeneous networks, White Paper, Jan. 2011. [Online]. Available: http://www.qualcomm.com/media/documents

[68] A. Damnjanovic, J. Montojo, Y. Wei, T. Ji, T. Luo, M. Vajapeyam, T. Yoo, O. Song, and D. Malladi, "A survey on 3GPP heterogeneous networks," *IEEE Wireless Commun.*, vol. 18, no. 3, pp. 10–21, Jun. 2011.

[69] Qualcomm, Neighborhood small cells for hyperdense deployments: Taking HetNets to the next level, Feb. 2013. [Online]. Available: http://www.qualcomm.com/media/documents/files/qualcomm-research-neighborhood-small-cell-deployment-model.pdf

[70] R. Ford, C. Kim, and S. Rangan, "Optimal user association in cellular networks with opportunistic third-party backhaul," Apr. 2013, arXiv preprint.

[71] T. Zwick, T. Beukema, and H. Nam, "Wideband channel sounder with measurements and model for the 60 GHz indoor radio channel," *IEEE Trans. Veh. Technol.*, vol. 54, no. 4, pp. 1266–1277, Jul. 2005.

[72] F. Giannetti, M. Luise, and R. Reggiannini, "Mobile and personal communications in 60 GHz band: A survey," *Wireless Pers. Commun.*, vol. 10, pp. 207–243, 1999.

[73] P. Smulders and A. Wagemans, "Wideband indoor radio propagation measurements at 58 GHz," *Electron. Lett.*, vol. 28, no. 13, pp. 1270–1272, Jun. 1992.

[74] T. Manabe, Y. Miura, and T. Ihara, "Effects of antenna directivity and polarization on indoor multipath propagation characteristics at 60 GHz," *IEEE J. Sel. Areas Commun.*, vol. 14, no. 3, pp. 441–448, Apr. 1996.

[75] H. Xu, V. Kukshya, and T. S. Rappaport, "Spatial and temporal characteristics of 60 GHz indoor channel," *IEEE J. Sel. Areas Commun.*, vol. 20, no. 3, pp. 620–630, Apr. 2002.

[76] A. Elrefaie and M. Shakouri, "Propagation measurements at 28 GHz for coverage evaluation of local multipoint distribution service," in *Proc. Wireless Commun. Conf.*, Aug. 1997, pp. 12–17.

[77] S. Seidel and H. Arnold, "Propagation measurements at 28 GHz to investigate the performance of local multipoint distribution service (LMDS)," in *Proc. Wireless Commun. Conf.*, Nov. 1995, pp. 754–757.

[78] T. S. Rappaport, E. Ben-Dor, J. Murdock, and Y. Qiao, "38 GHz and 60 GHz angle-dependent propagation for cellular & peer-to-peer wireless communications," in *Proc. IEEE Int. Conf. Commun.*, Jun. 2012, pp. 4568–4573.

[79] T. S. Rappaport, E. Ben-Dor, J. Murdock, Y. Qiao, and J. Tamir, "Cellular broadband millimeter wave propagation and angle of arrival for adaptive beam steering systems," in *Proc. IEEE Radio Wireless Symp.*, Jan. 2012, pp. 151–154.

[80] J. Murdock, E. Ben-Dor, Y. Qiao, J. Tamir, and T. S. Rappaport, "A 38 GHz cellular outage study for an urban outdoor campus environment," in *Proc. IEEE Wireless Commun. Netw. Conf.*, Apr. 2012, pp. 3085–3090.

[81] G. R. MacCartney, Jr., J. Zhang, S. Nie, and T. S. Rappaport, "Path loss models for 5G millimeter wave propagation channels in urban microcells," in *Proc. IEEE Global Telecommun. Conf.*, Dec. 2013.

[82] J. A. Wells, "Faster than fiber: The future of multi-Gb/s wireless," *IEEE Microw. Mag.*, vol. 10, no. 3, pp. 104–112, May 2009.

[83] 3GPP, "Further advancements for E-UTRA physical layer aspects," TR 36.814 (release 9), 2010.

[84] S. Pinel, S. Sarkar, P. Sen, B. Perumana, D. Yeh, D. Dawn, and J. Laskar, "A 90 nm CMOS 60 GHz radio," in *Proc. IEEE Int. Solid-State Circuits Conf.*, 2008, DOI: 10.1109/ISSCC.2008.4523091.

[85] C. Marcu, D. Chowdhury, C. Thakkar, J.-D. Park, L.-K. Kong, M. Tabesh, Y. Wang, B. Afshar, A. Gupta, A. Arbabian, S. Gambini, R. Zamani, E. Alon, and A. Niknejad, "A 90 nm CMOS low-power 60 GHz transceiver with integrated baseband circuitry," *IEEE J. Solid-State Circuits*, vol. 44, no. 12, pp. 3434–3447, Dec. 2009.

[86] A. Alkhateeb, O. E. Ayach, G. Leus, J. Robert, and W. Heath, "Hybrid precoding for millimeter wave cellular systems with partial channel knowledge," in *Proc. Inf. Theory Appl. Workshop*, Feb. 2013, DOI: 10.1109/ITA.2013.6522603.

[87] A. Lozano, "Long-term transmit beamforming for wireless multicasting," in *Proc. Int. Conf. Acoust. Speech Signal Process.*, 2007, vol. 3, pp. III-417–III-420.

[88] Q. Li, H. Niu, G. Wu, and R. Q. Hu, "Anchor-booster based heterogeneous networks with mmwave capable booster cells," in *Proc. IEEE Globecom Workshop*, Dec. 2013, to be published.

[89] C. Bontu and E. Illidge, "DRX mechanism for power saving in LTE," *IEEE Commun. Mag.*, vol. 47, no. 6, pp. 48–55, Jun. 2009.

[90] D. Parker and D. Z. Zimmermann, "Phased arrays—Part I: Theory and architecture," *IEEE Trans. Microw. Theory Tech.*, vol. 50, no. 3, pp. 678–687, Mar. 2002.

[91] K.-J. Koh and G. M. Rebeiz, "0.13-m CMOS phase shifters for X-, Ku- and K-band phased arrays," *IEEE J. Solid-State Circuits*, vol. 42, no. 11, pp. 2535–2546, Nov. 2007.

[92] K.-J. Koh and G. M. Rebeiz, "A millimeter wave (4045 GHz) 16-element phased-array transmitter in 0.18-m SiGe BiCMOS technology," *IEEE J. Solid-State Circuits*, vol. 44, no. 5, pp. 1498–1509, May 2009.

[93] P. E. Crane, "Phased array scanning system," U.S. Patent 4 731 614, Mar. 15, 1988.

[94] S. Raman, N. S. Barker, and G. M. Rebeiz, "A W-band dielectric-lens-based integrated monopulse radar receive," *IEEE Trans. Microw. Theory Tech.*, vol. 46, no. 12, pp. 2308–2316, Dec. 1998.

[95] X. Guan, H. Hashemi, and A. Hajimiri, "A fully integrated 24-GHz eight-element phased-array receiver in silicon," *IEEE J. Solid-State Circuits*, vol. 39, no. 12, pp. 2311–2320, Dec. 2004.

[96] G. Fettweis, F. Guderian, and S. Krone, "Entering the path towards terabit/s wireless links," in *Proc. IEEE Design Autom. Test Eur.*, 2011, DOI: 10.1109/DATE.2011.5763075.

[97] H. Zhang, S. Venkateswaran, and U. Madhow, "Analog multitone with interference suppression: Relieving the ADC bottleneck for wideband 60 GHz systems," in *Proc. IEEE Global Telecommun. Conf.*, Nov. 2012, pp. 2305–2310.

[98] S. Tavildar, S. Shakkottai, T. Richardson, J. Li, R. Laroia, and A. Jovicic, "FlashLinQ: A synchronous distributed scheduler for peer-to-peer ad hoc networks," in *Proc. Allerton Conf. Commun. Control Comput.*, Allerton, IL, USA, Oct. 2010, pp. 514–521.

[99] A. So and B. Liang, "Effect of relaying on capacity improvement in wireless local area networks," in *Proc. IEEE Wireless Commun. Netw. Conf.*, Mar. 2005, vol. 3, pp. 1539–1544.

[100] R. Schoenen, W. Zirwas, and B. H. Walke, "Capacity and coverage analysis of a 3GPP-LTE multihop deployment scenario," in *Proc. IEEE Int. Conf. Commun.*, May 2008, pp. 31–36.

[101] A. B. Saleh, S. Redana, B. Raaf, and J. Hamalainen, "Comparison of relay and Pico eNB deployments in LTE-advanced," in *Proc. IEEE Veh. Technol. Conf.*, Sep. 2009, DOI: 10.1109/VETECF.2009.5378828.

[102] S. W. Peters, A. Y. Panah, K. T. Truong, and R. W. Heath, "Relay architectures for 3GPP LTE-advanced," *EURASIP J. Wireless Commun. Netw.*, 2009, DOI: 10.1155/2009/618787.

[103] G. D. Durgin and T. S. Rappaport, "Theory of multipath shape factors for small-scale fading wireless channels," *IEEE Trans. Antennas Propag.*, vol. 48, no. 5, pp. 682–693, May 2000.

[104] M. Vetterli, P. Marziliano, and T. Blu, "Sampling signals with finite rate of innovation," *IEEE Trans. Signal Process.*, vol. 50, no. 6, pp. 1417–1428, Jun. 2002.

[105] G. Taubock and F. Hlawatsch, "A compressed sensing technique for OFDM channel estimation in mobile environments: Exploiting channel sparsity for reducing pilots," in *Proc. IEEE Int. Conf. Acoust. Speech Signal Process.*, May 2008, pp. 2885–2888.

[106] J. Haupt, W. U. Bajwa, G. Raz, and R. Nowak, "Toeplitz compressed sensing matrices with applications to sparse channel estimation," *IEEE Trans. Inf. Theory*, vol. 56, no. 11, pp. 5862–5875, Nov. 2010.

[107] Y. Barbotin, A. Hormati, S. Rangan, and M. Vetterli, "Estimating sparse MIMO channels having common support," in *Proc. IEEE Int. Conf. Acoust. Speech Signal Process.*, May 2011, pp. 2920–2923.

[108] J. I. Tamir, T. S. Rappaport, Y. C. Eldar, and A. Aziz, "Analog compressed sensing for RF propagation channel sounding," in *Proc. IEEE Int. Conf. Acoust. Speech Signal Process.*, 2012, pp. 5317–5320.

[109] 3GPP, "Evolved universal terrestrial radio access (E-UTRA) and evolved universal terrestrial radio access network (E-UTRAN); overall description; stage 2," TS 36.300 (release 10), 2010.

[110] G. Yuan, X. Zhang, W. Wang, and Y. Yang, "Carrier aggregation for LTE-advanced mobile communication systems," *IEEE Commun. Mag.*, vol. 48, no. 2, pp. 88–93, Feb. 2010.

ABOUT THE AUTHORS

Sundeep Rangan (Senior Member, IEEE) received the B.A.Sc. degree from the University of Waterloo, Waterloo, ON, Canada and the M.Sc. and Ph.D. degrees from the University of California, Berkeley, Berkeley, CA, USA, all in electrical engineering.

He has held postdoctoral appointments at the University of Michigan, Ann Arbor, MI, USA and Bell Labs. In 2000, he co-founded (with four others) Flarion Technologies, a spinoff of Bell Labs that developed Flash OFDM, the first cellular OFDM data system. In 2006, Flarion was acquired by Qualcomm Technologies. He was a Director of Engineering at Qualcomm involved in OFDM infrastructure products. He joined the Electrical and Computer Engineering Department at the NYU Polytechnic School of Engineering, Brooklyn, NY, USA, in 2010, where he is currently an Associate Professor. His research interests are in wireless communications, signal processing, information theory, and control theory.

Theodore S. Rappaport (Fellow, IEEE) received the B.S., M.S., and Ph.D. degrees in electrical engineering from Purdue University, West Lafayette, IN, USA, and is a Distinguished Engineering Alumnus of his alma mater.

He is the David Lee/Ernst Weber Professor of Electrical and Computer Engineering at the Polytechnic Institute of New York University (NYU-Poly), Brooklyn, NY, USA and is a Professor of Computer Science at New York University's Courant Institute of Mathematical Sciences. He is also a Professor of Radiology at the NYU School of Medicine. He is the founding director of NYU WIRELESS, one of the world's first academic research center to combine engineering, computer science, and medicine. Earlier, he founded two of the world's largest academic wireless research centers: the Wireless Networking and Communications Group (WNCG) at the University of Texas at Austin, Austin, TX, USA, in 2002, and the Mobile and Portable Radio Research Group (MPRG), now known as Wireless@Virginia Tech, in 1990. He is a pioneer in radio wave propagation for cellular and personal communications, wireless communication system design, and broadband wireless communications circuits and systems at millimeter-wave frequencies. His research has influenced many international wireless standard bodies over three decades, and he and his students have invented measurement equipment, simulation methodologies, and analytical approaches for the exploration and modeling of radio propagation channels and communication system design in a vast range of spectrum bands for emerging wireless systems. More recently, his work has explored the millimeter-wave bands for future broadband access. As a faculty member, he has advised approximately 100 students who continue to accomplish great things in the communications, electromagnetics, and circuit design fields throughout industry, academia, and government. In 1989, he founded TSR Technologies, Inc., a cellular radio/PCS software radio manufacturer that he sold in 1993 to what is now CommScope, Inc. (taken private in 2011 by Carlyle Group). In 1995, he founded Wireless Valley Communications, Inc., a pioneering creator of site-specific radio propagation software for wireless network design and management that he sold in 2005 to Motorola. He has served on the Technological Advisory Council of the Federal Communications Commission, assisted the governor and CIO of Virginia in formulating rural broadband initiatives for Internet access, and conducted research for the National Science Foundation (NSF), the U.S. Department of Defense, and dozens of global telecommunications companies throughout his career. He is one of the most highly cited authors in the wireless field, having published over 200 technical papers and over 20 books, and is a highly sought-after expert. He has over 100 patents issued or pending.

Elza Erkip (Fellow, IEEE) received the B.S. degree in electrical and electronics engineering from Middle East Technical University, Ankara, Turkey and the M.S. and Ph.D. degrees in electrical engineering from Stanford University, Stanford, CA, USA.

In the past, she has held positions at Rice University, Houston, TX, USA and at Princeton University, Princeton, NJ, USA. Currently, she is a Professor of Electrical and Computer Engineering at the New York University Polytechnic School of Engineering, Brooklyn, NY, USA. Her research interests are in information theory, communication theory, and wireless communications.

Dr. Erkip received the National Science Foundation CAREER Award in 2001, the IEEE Communications Society Rice Paper Prize in 2004, and the ICC Communication Theory Symposium Best Paper Award in 2007. She co-authored a paper that received the ISIT Student Paper Award in 2007. Currently, she is a General Chair of ISIT 2013 and member of the Board of Governors of the Information Theory Society. She was an Associate Editor of the IEEE Transactions on Information Theory from 2009 to 2011, an Associate Editor of the IEEE Transactions on Information Communications from 2006 to 2009, a Publications Editor of the IEEE Transactions on Information Theory from 2006 to 2009, and a guest editor of the IEEE Signal Processing Magazine in 2007. She was the Technical Program Co-Chair of WiOpt 2011, the Co-Chair of the GLOBECOM Communication Theory Symposium in 2009, the Publications Chair of ITW Taormina in 2009, the MIMO Communications and Signal Processing Technical Area Chair of the Asilomar Conference on Signals, Systems, and Computers in 2007, and the Technical Program Co-Chair of the Communication Theory Workshop in 2006.